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AN AQL-AOQL PROCESS CONTROL SYSTEM FOR FRACTION DEFECTIVE.

9 Research Report, No. 14 RR-78-8

by

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This research reports on an acceptance control chart system based on a combination of AQL and AOQL. It is designed to augment and parallel ISE TR 76-4 "Procedure for Maintenance and Rework Process Quality Control Based on Random Sampling" in those situations in which large numbers of essentially identical items are produced.

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ABSTRACT

This research reports on an acceptance control chart system based on a combination of AQL and AOQL. It is designed to augment and parallel ISE TR 76-4 "Procedure for Maintenance and Rework Process Quality Control Based on Random Sampling" in those situations in which large numbers of essentially identical items are produced.

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AN AQL - AOQL PROCESS CONTROL
SYSTEM FOR FRACTION DEFECTIVE

1. SCOPE

1.1 Application. This document establishes inspection plans and procedures for controlling processes in which there is homogeneity in the items produced. It is intended to be used as a companion to PROCEDURE FOR MAINTENANCE AND REWORK PROCESS QUALITY CONTROL BASED ON RANDOM SAMPLINGS (hereafter referred to as the PROCEDURE MANUAL) in those shops processing essentially like items. Sampling is based upon the number of essentially identical items produced during a pre-determined period of time. The system is intended to be applied to continuously operating processes, not to lot or batches of completed items.

1.2 Objectives. Objectives of the process control program are covered in the PROCEDURE MANUAL.

1.3 Definitions. Certain terms, symbols, and definitions are different from those stipulated in the PROCEDURE MANUAL. In order to clarify meaning as they pertain to this system, they are defined in this section.

AFI = Average Fraction Inspected. The proportion of total production of a shop which will be inspected, on the average, when the percent defective is at a stipulated level.

AOQ = Average Outgoing Quality. The average quality of outgoing production, in percent defective, when the rules and procedures of the sampling system are adhered to.

AOQL = Average Outgoing Quality Limit. The maximum value that average outgoing quality, in percent defect, will reach when the switching rules and procedures of the sampling system are followed.

AQL = Acceptable Quality Level. The maximum rate of defect production, in percent defective, which for purposes of sampling inspection can be considered acceptable as a process average.

CL = Upper Control Limit for Percent Defective Control Chart (PDCC).

CL_r = Control Limit under Reduced sampling inspection.

CL_n = Control Limit under Normal sampling inspection and under Mandatory inspection.

CL_t = Control Limit under Tightened sampling inspection.

LOT = The number of items produced during a pre-determined period of time, such as an hour, a shift, or a day, etc. The Lot definition may apply to a specific processor or to a shop.

LQ = Limiting Quality. That level of poor quality production, in terms of percent defective, at which the probability is 90% that the processor or shop will be on Mandatory (100%) inspection. Values of the LQ are tabulated in Table IV.

Mandatory. Required 100% inspection of all units.

N_n = The sample subgroup size, or number of units from a Lot to be inspected, when on Normal sampling inspection. Also, the subgroup size when on Mandatory inspection.

N_r = The sample subgroup size when on Reduced sampling inspection.

N_t = The sample subgroup size when on Tightened sampling inspection.

Inspection Level. The level of severity of the sampling system in terms of the relationship between the AQL and the AOQL. This system corresponds to Inspection Level II in the PROCEDURE MANUAL.

Sampling Intensity. The designation of the intensity in terms of sample size between Normal, Reduced, and Tightened sampling.

Sampling System. The collection of designated inspection intensities, including three sampling intensities plus Mandatory (100%) inspection, and switching rules prescribed for the stipulated AQL and Lot size.

Switching Rules. The decision rules to be applied to decisions as to when the change from one sampling intensity to another or to (and from) Mandatory inspection.

p = The fraction defective in production lots.

$\bar{p}$ = The average fraction defective in a sequence or production lots. It is used to estimate the actual process average fraction defective.

2. DETERMINING A SAMPLING SYSTEM

2.1 <u>The Sampling System - Described</u>. The sampling system is comprised of a set of four inspection intensities, one sampling intensity each for Normal, Reduced, and Tightened inspection, plus Mandatory (100%) inspection, and the decision rules and procedures required to determine when a change in inspection intensity is to be made. A general schematic diagram of the operation of the system is shown in Figure 1 (p. 6). When all of the decision rules in the system are followed, the system provides for a fixed AOQL and is designed to minimize the AFI if the shop in question is operating at or below the stipulated AQL.

The system uses the principles of the Shewhart control chart and is sometimes referred to as acceptance control charting. If the control chart indicates a process in control, then reliable estimates of the process average fraction defective may be made.

2.2 <u>Inspection Level</u>. This system corresponds to Inspection Level II in the PROCEDURE MANUAL. That is, for any designated AQL, the AOQL is approximately 1.6 times the AQL.

The AOQL acts as the "insurance policy" of the system. It will insure that, on the average, quality exiting the shop will be no worse than the AOQL value assuming that the switching rules are followed and that, when on Mandatory inspection, all defects are found and corrected.

2.3 Determining the Lot Size. The Lot Size is the number of items produced during a predetermined period of time, such as an hour, a shift, a day or a week. Normally it shall be one week. Once the time interval is chosen, it is necessary to determine the number of items to be completed during that period in the shop in question.

The Tables (I through V) show Lot Size ranges in number of items processed in the first column. The appropriate row of these tables is entered by locating the row with the lot size range containing number of items produced in a specific shop, during the predetermined time interval, e.g., one week.

2.4 Assigning the AQL. The AQL, together with the lot size, is used to identify the applicable sampling system in the Tables. Once set, the designation of the sampling system is fixed in the column for the AQL and the row for the Lot Size.

The AQL value will be established for each shop in accordance with existing instructions.

2.4.1. Preferred AQL's. The values of the AQL's given in these tables are known as preferred AQL's. Preferred AQL values, listed in the following table, should be used.

For specified AQL values falling within these ranges			Use this AQL value
-	to	0.440	0.40
0.440	to	0.699	0.65
0.700	to	1.09	1.0
1.10	to	1.64	1.5
1.65	to	2.79	2.5
2.80	to	4.39	4.0
4.40	to	6.99	6.5
7.00	to	12.5	10.0

2.4.2 Limitation. The designation of an AQL shall not imply that the verifier or artisan has the right to knowingly pass a defective item from the shop.

2.5 Determining Sample Sizes (N_n, N_r, N_t). The number of items to be inspected under Normal (N_n), Reduced (N_r), and Tightened (N_t) inspection are found by: entering the Table I in the row indicated by the lot size and the column indicated for the designated AQL.

2.6 Normal, Reduced, and Tightened Sampling Intensities.

2.6.1 Initiation of Inspection. Normal sampling (N_n) will be used at the start of inspection unless otherwise directed by the responsible authority.

2.6.2 Switching Sampling Intensities. Figure 1 illustrates the decision rules used to determine shifts from one sampling intensity to another or to (or from) Mandatory inspection.

2.6.3 Normal to Tightened. A shift from Normal (N_n) to Tightened (N_t) sampling is required if, on the Percent Defective Control Chart, 7 consecutive points fall above the AQL while on Normal sampling.

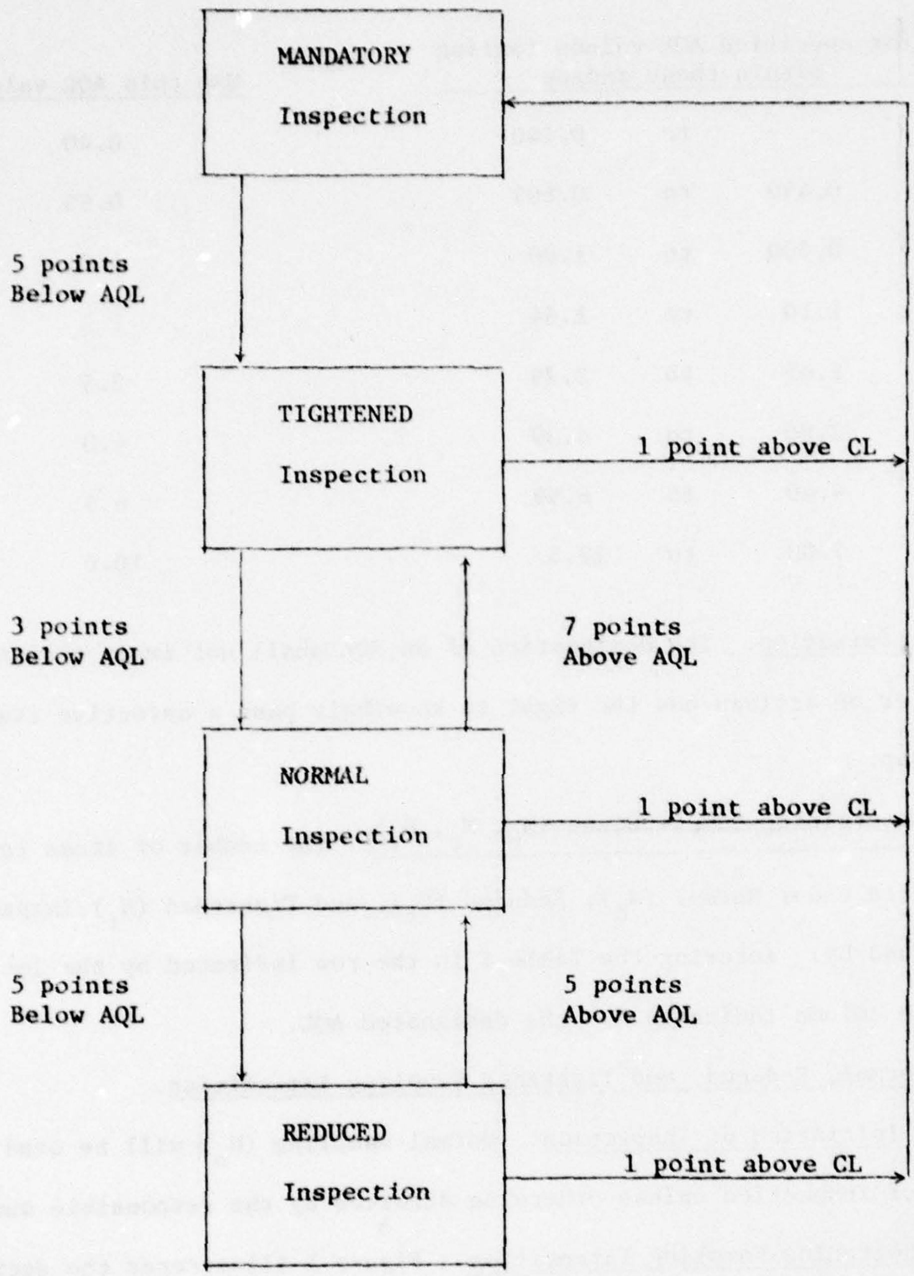


Figure 1: Flow Chart of Sampling System.

2.6.4 Tightened to Normal. A shift from Tightened (N_t) to Normal (N_n) sampling is allowed if, on the Percent Defective Control Chart, 3 consecutive points fall below the AQL while on Tightened sampling.

2.6.5 Normal to Reduced. A shift from Normal (N_n) to Reduced (N_r) sampling is allowed if, on the Percent Defective Control Chart, 5 consecutive points fall below the AQL while on Normal sampling.

2.6.6 Reduced to Normal. A shift from Reduced (N_r) to Normal (N_n) sampling is required if, on the Percent Defective Control Chart, 5 consecutive points fall above the AQL while on Reduced sampling.

2.6.7 Normal, Reduced, or Tightened to Mandatory. A point above the control limit (CL) on the Percent Defective Control Chart requires an immediate shift to mandatory (100%) inspection. This rule applies regardless of the level of sampling currently in effect in the shop.

2.6.8 Implementing Mandatory Inspection. Mandatory (100%) inspection may be instituted as the result of a sample data point falling above the control limit (CL) on the Percent Defective Control Chart or when directed to do so by a responsible authority in consultation with the Supervisor of the Components Verification Branch. This last case will usually result from downstream information feedback or prior knowledge of an expected high rate of defectives due to a particular component or artisan.

When Mandatory inspection has been in force, the switch to Tightened sampling inspection frequently will occur during inspection of a Lot. In this case, the Same Size, N_t, should be reduced for the remainder of the Lot in proportion to the balance of the remaining items in the Lot. Unless at least one-half of the Lot remains, no point is plotted on the Percent Defective Control Chart and the sampling result during the remainder of

the Lot is not counted toward the requirements for a shift to the Normal sampling intensity.

2.6.9 Mandatory to Tightened Sampling Inspection. When mandatory inspection applies to the entire shop, a point is plotted on the PDCC for each N_n items inspected, i.e., N_n is the subgroup size. Mandatory inspection shall remain in force until 5 consecutive points fall below the control limit (CL) on the PDCC at which time inspection shall revert to the Tightened sampling intensity.

3. OPERATING THE SAMPLING SYSTEM

3.1 Daily Verification Record. The Daily Verification Record (DVR) is the basic data collection source for the Sampling System. (See Figure 3 for a sample DVR). It serves two principal purposes. First, it provides necessary input data for the "Mini-System" defect reporting system. Second, it provides the data necessary to prepare the Percent Defective Control Chart (PDCC) and apply the switching rules of the Sampling System.

The DVR is prepared in accordance with QRAINST 4855.21G with the following additions and exceptions:

(1) A separate DVR form is to be prepared for each shop.

(2) All characteristics from the QCL at the current stage of rework which are the responsiblity of the Certifier being check are to be verified.

(3) After the completion of the verification of characteristics on the component, extend the line beneath the last characteristic to the right margin of the DVR form and indicate in the right margin whether the item was defective (X) or good (0).

3.2 Percent Defective Control Chart (PDCC). The Percent Defective Control Chart serves two vital purposes in achieving the objectives of the Sampling

MONTHLY VERIFICATION REPORT

INSPECTION LEVEL [X] AQL [1.0] AOQL [1.5] LQ [4.5]

Shop No. 9XXXX

QA Specialist Jones

Period 5-30 To 6-24

AVERAGE UNITS/MH [—]

	UNITS	MH EXPENDED
Wk 1	550	
Wk 2	795	
Wk 3	680	
Wk 4	580	
TOTAL	2605	
Avg.	651	
Prod. Interval	650	

SAMPLE HOURS	SAMPLE SIZE	CONTROL LIMIT
H_r	N_r 26	CL_r 5.8
H_n	N_n 66	CL_n 3.8
H_t	N_t 105	CL_t 3.3

ADDITIONAL ACTIVITIES

~~Sample Hrs.~~ Units Wk	1	2	3	4	Total
Required	105	105	105	105	420
Completed	105	105	105	105	420
% Completed					100%

[O] Sample verified, no defects

[X] Sample verified, 1 or more defects

[ ] Sample skipped

[M] Mandatory inspection

(OVER)

Sampling Level (R,N,T,M)	S	M	T	W	T	F	S
T		30) 0/25	0/20	0/20	0/20	0/20	
T		0/20	1/25	0/20	0/20	0/20	
T		0/20	0/20	0/20	0/20	0/25	
T		0/20	0/20	0/25	0/20	0/20	

REMARKS OA Mandatory 5/27

(OVER)

RSL 5-77

SAMPLING SEQUENCE

No.	CERTIFIER	No.	CERTIFIER	No.	CERTIFIER	No.	CERTIFIER
1		24		47		70	
2		25		48		71	
3		26		49		72	
4		27		50		73	
5		28		51		74	
6		29		52		75	
7		30		53		76	
8		31		54		77	
9		32		55		78	
10		33		56		79	
11		34		57		80	
12		35		58		81	
13		36		59		82	
14		37		60		83	
15		38		61		84	
16		39		62		85	
17		40		63		86	
18		41		64		87	
19		42		65		88	
20		43		66		89	
21		44		67		90	
22		45		68		91	
23		46		69		92	

MANDATORY B&C - SPECIAL STUDIES

Figure 2. Sample Monthly Verification Report Form

DATE (1–4)	SPEC. (5–6)
4169	4Ø

VERIFICATION RECORD (DAILY)

SHOP (7–11)	CERTIFIER (12–16)	PROGRAM (17–21)	DOCUMENT (22–29)	LINE (30–33)	SERIAL NO. (34–39)	DIS. (40)	CC (72)	AC (73)	PROC. (74–75)	ADDRESS (77–80)	
94242	A2656	39DEE	C4242Ø1	Ø1	8YN163	Ø	2				
				Ø2		Ø	2				
				Ø3		Ø	2				
				Ø4		Ø	2				
				Ø5		Ø	2				
				Ø6		Ø	2				
				Ø7		Ø	2				
				Ø8		Ø	2				
				Ø9		Ø	2				
				1Ø		Ø	2				O
	A985			Ø1	CXA217	1	2				
				Ø2		Ø	2				
				Ø3		Ø	2				
				Ø4		Ø	2				
				Ø5		Ø	2				
				Ø6		Ø	2				
				Ø7		Ø	2				
				Ø8		Ø	2				
				Ø9		Ø	2				
				1Ø		1	2				
				11		Ø	2				
				12		Ø	2				
				13		1	2				
				14		Ø	2				
				15		Ø	2				X
							2				
							2				
							2				
							2				
							2				

Figure 3. Sample Daily Verification Record (DVR) Form

System. First, the plotted points for defective items for each Lot, or each Mandatory inspection subgroup, and their location with respect to the designated AQL and Control Limit (CL), signal when a shift to a different intensity of sampling or a shift to or from Mandatory inspection is to occur. Second, when displayed in the shop, it informs all Certifiers as to the level of shop performance over a period of time both as to quality level and consistency.

Figure 4 illustrates the PDCC Data Summary form used to accumulate verfication data from the DVR's and Figure 5 illustrates the Percent Defective Control Chart.

A separate Percent Defective Control Chart is maintained for each item or class of items. Each chart can show the verification inspection results for a number of Lot sizes, when sampling is in force, or subgroups if Mandatory inspection is in force.

3.2.1 Using the Percent Defective Control Chart Data Summary Form

(1) Record, in the space provided at the top of the form, the designated AQL, the QA Specialist's name, and the shop and item nomenclature.

(2) The data sheet is divided into blocks allowing the QA Specialist to record data each day from the DVR's for the shop for a normal production lot interval, one week. When Mandatory inspection is in force, the data for one subgroup should be entered in a block. This may be less than one day's record or may span parts of successive days.

a) Indicate in the block whether the sampling intensity in use is Reduced (R), Normal (N), Tightened (T), or Mandatory (M).

Figure 4. Sample PDCC Data Summary Form

QUALITY VERIFICATION DATA FORM
PERCENT DEFECTIVE CONTROL CHART

AQL	QA SPECIALIST	ITEM	SHOP
1.0	Jones	Pump Q15	9XXXX

	DATE	DEFECTIVES d	No. of Items N	$\sum d$	$\sum N$
R, N, T, M [T] N = [105]	5-29	0	25	0	25
$p = \frac{\sum d}{\sum N} = \frac{0}{105}$	5-30	0	20	0	45
	6-1	0	20	0	65
	6-2	0	20	0	85
100p = [0.0]	6-3	0	20	0	105
CL = [3.3] (Table II)					
R, N, T, M [T] N = [105]	6-6	0	20	0	20
$p = \frac{\sum d}{\sum N} = \frac{1}{105}$	6-7	1	25	1	45
	6-8	0	20	1	65
	6-9	0	20	1	85
100p = [1.0]	6-10	0	20	1	105
CL = [3.3] (Table II)					
R, N, T, M [T] N = [105]	6-13	0	20	0	20
$p = \frac{\sum d}{\sum N} = \frac{0}{105}$	6-14	0	20	0	40
	6-15	0	20	0	60
	6-16	0	20	0	80
100p = [0.0]	6-17	0	25	0	105
CL = [3.3] (Table II)					
R, N, T, M [T] N = [105]	6-20	0	20	0	20
$p = \frac{\sum d}{\sum N} =$	6-21	0	20	0	40
	6-22	0	25	0	65
	6-23	0	20	0	85
100p = [0.0]	6-24	0	20	0	105
CL = [3.3] (Table II)					
R, N, T, M [T] N = [105]	6-27	0	20	0	20
$p = \frac{\sum d}{\sum N} = \frac{0}{105}$	6-28	0	20	0	40
	6-29	0	25	0	65
	6-30	0	20	0	85
100p = [0.0]	7-1	0	20	0	105
CL = [3.3] (Table II)					
R, N, T, M [N] N = [66]		0	16	0	16
$p = \frac{\sum d}{\sum N} = \frac{1}{66}$		0	16	0	32
		1	16	1	48
		0	9	1	57
100p = [1.5]	7-8	0	9	1	66
CL = [3.8] (Table II)					

b) Enter the number of items to be inspected (N_r, N_n, or N_t) in the "N" space.

NOTE: When on Mandatory inspection, the subgroup size is N_n. Inspection results are recorded sequentially on the DVR until N_n items have been verified and are then totalled in one block of the Data Summary form. These data form one subgroup point plot on the Percent Defective Control Chart. One block on the Data Summary is used for each subgroup. This deviation from standard practice continues until a shift is made to Tightened inspection.

c) Enter in the appropriate space in a block the date, number of defects found, (d), and total number of items for the day (or subgroup), n.

d) Add together the daily count of defectives found and enter in the "$\sum d$" column.

e) Add together the daily items of inspection and enter in the "$\sum n$" column.

f) As soon as the value in the "$\sum n$" column equals the value of "N" indicated for the block, Verification Inspection for that Lot (or subgroup) is terminated.

(3) Determine the value of p, fraction defective, for the production lot interval (or subgroup) by dividing "$\sum d$" by "$\sum n$". Enter this value in the appropriate space on the Data Summary and on the Percent Defective Control Chart. For convenience, the value of p should be converted to percent by multiplying by 100.

(4) The value of the appropriate Control Limit, "CL", is determined from Table II. These numbers are given in percent defective.

3.2.2 Using the Percent Defective Control Chart (PDCC). Required data for the Percent Defective Control Chart are taken from the PDCC Data Summary form. In initiating a chart, the value of the AQL is entered at the top of the chart and drawn as a solid line across the face of the chart after the chart has been appropriately scaled. AQL's are given in percent defective.

(1) The date of entry for the Lot size (or subgroup), the value of 100p (percent defective), and the Control Limit (CL) are entered on the lower portion of the chart.

(2) On the vertical line directly above the data are plotted the values of 100p and CL. The latest value of 100p is connected to the previous value by a solid line. The latest value of the CL is connected to the previous value by a dash line.

(3) Finally, the Switching Rules described in Paragraph 2.7 and illustrated in Figure 1 are applied to determine the intensity of inspection required for the next Lot (or subgroup).

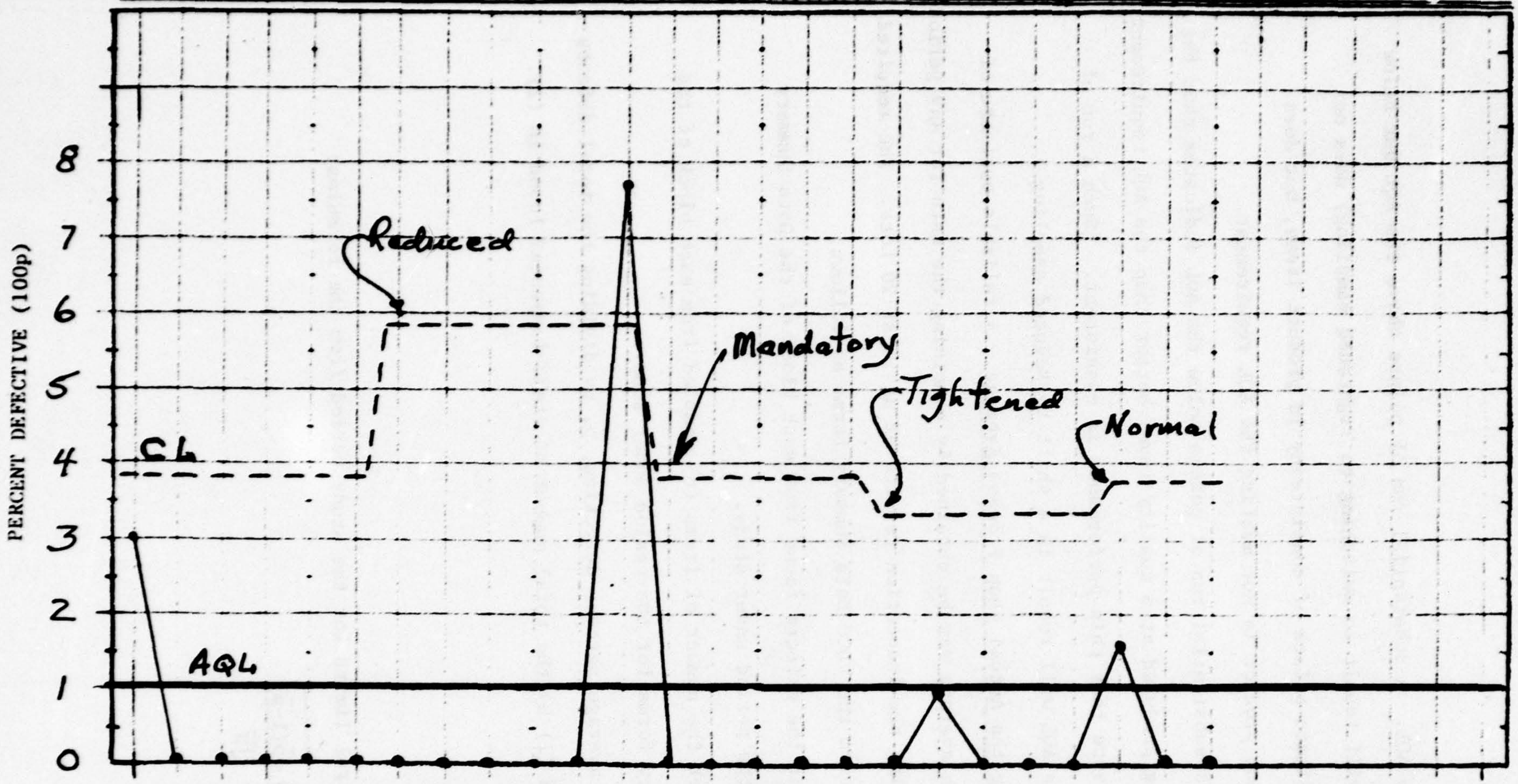
3.2.3 Interpreting the Percent Defective Control Chart. The central line and control limit on the Percent Defective Control Chart are determined from the value of the designated AQL and the sample or subgroup size, N_r, N_n, or N_t.

Standard values of the Control Limit (CL) are given in Table II. Standard values of CL are provided for all standard values of AQL and ranges of sample sizes contained in the master sample size table, Table I.

If after a succession of points have been plotted on the control chart all points fall below the CL, it may be assumed that the process is operating

PERCENT DEFECTIVE CONTROL CHART

AQL = 1.0	QA SPECIALIST Jones	ITEM Pump Q15	SHOP 9XXXX



DATE	3-4	3-11	3-18	3-25	4-1	4-8	4-15	4-22	4-29	5-6	5-13	5-20	5-22	5-23	5-23/4	5-24/5	5-25/6	6-3	6-10	6-17	6-24	7-1	7-8	7-15	7-22
100p	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.5	0.0	0.0
CL	3.8	3.8	3.8	3.8	3.8	3.8	5.8	5.8	5.8	5.8	5.8	5.8	3.8	3.8	3.8	3.8	3.8	3.3	3.3	3.3	3.3	3.3	3.8	3.8	3.8

Figure 5. Sample Percent Defective Control Chart

at or below the AQL. A substantial run of points above the AQL but below the CL (which will result in switching to Tightened sampling) does not necessarily indicate a lack of consistency in product items, but does indicate that the product is not meeting the AQL requirement.

Likewise, a substantial run of points below the AQL indicates that the product is being produced at a quality level better than the AQL requirement but does not insure that this performance is consistent. (Such a run of points below the AQL will result in a shift to Reduced sampling.)

3.2.4 <u>Estimating the Actual Shop Process Average</u>. A reliable estimate of the shop process average may be obtained by combining the data for any period of time containing the inspection results of at least 20 Lots. The required data are taken from the PDCC Data Summary forms as follows:

(1) Add together the defects found from each block of the Data Summary forms for the period under study.

(2) Add together the number of items (n) sampled from each block of the Data Summary forms for the period under study.

(3) Obtain the average percent defective, $\bar{p}$, by dividing the total defects obtained in (1) by the total number of items inspected found in (2). That is:

$$\bar{p} = \frac{\sum d}{\sum n}$$

(4) Derive control limits for the study period from the formulas:

$$UCL = \bar{p} + \frac{3\sqrt{\bar{p}(1-\bar{p})}}{\sqrt{N}}$$

$$LCL = \bar{p} - \frac{3\sqrt{\bar{p}(1-\bar{p})}}{\sqrt{N}}$$

where:

UCL = Upper Control Limit

LCL = Lower Control Limit (if positive)

(no LCL exists if the calculation leads to a negative number).

N = Sample or Subgroup size for each data point.

(5) Convert these control limits to percent by multiplying them by 100 and plot them on the Percent Defective Control Chart. Since the PDCC already has an upper control limit based on the AQL plotted on it, these new control limits should be plotted in a different color.

(6) If for the study period all of the plotted points fall within these Control Limits, $\bar{p}$ is a reliable estimate of the true process average for the shop.

If points fall outside the control limits based on $\bar{p}$, the process is not operating in control. This may be the case even if all of the points fall inside the limits based on the AQL. (Limits based on the AQL are based on a predetermined maximum; those based on $\bar{p}$ are based on the results of actual shop operations.) A reliable estimate of the true process average cannot be obtained for a shop that is not operating in a state of statistical control.

3.3 <u>Chance Interception of Defects</u>. An objective of the procedures detailed herein is to provide a formalized and mathematically sound set of rules for drawing random samples of work being performed in a shop. It frequently

occurs, however, that in the process of executing the procedures, a Q.A. Specialist intercepts errors or finds defective material "by accident." These are chance events if they occur outside the intent of the sampling system procedures.

Naturally, a Q.A. Specialist reports <u>all</u> defects and errors regardless of the source. However, chance defect interceptions are NOT recorded with the planned sample data and are NOT used for normal shop control charting. Defects found on a product unit not selected under the procedures of the sampling system, or those attributable to another Certifier or another shop, are to be recorded separately from the sample data on a separate DVR or carefully segregated from the planned sample data results on the DVR.

If the chance defect intercepted is, in fact, chargeable to the shop being verified, a notation of the fact should be made on the MVR and, at the discretion of the Q.A. Specialist, on the Percent Defective Control Chart. PDR's should be made out following standard procedure. It is never acceptable for a Q.A. Specialist, Certifier, or Shop Supervisor to knowingly pass a defective item from the shop unless handled in accordance with applicable instruction.

4. MEASURES OF SYSTEM EFFECTIVENESS

4.1 General Explanation. The procedures described in this process control system are based upon the following measures of sampling system effectiveness:

(1) Coded against an AQL wherein the probability is approximately 1% of switching from sampling inspection to Mandatory inspection of the shop process quality is at or below the AQL.

(2) Provides for a fixed AOQL for each value of the AQL.

(3) Minimizes the Average Fraction Inspected (AFI) if the process quality level is at or below the AQL.

Coupled with the characteristics described are other characteristics which may be of interest. These include the Limiting Quality (LQ) point, which is the process level in percent defective at which there is a 90% probability of being on Mandatory inspection. These values are given in Table IV . Operating Characteristic (OC) curves also provide valuable information about the operation of the system at any given levels of shop quality performance. Figure 6 provides charts of the AFI, AOQ, and OC curves for all sampling systems contained herein. Since the OC curves apply to a sampling system rather than a specific sampling plan (the combination of plans for a designated value of AQL and Lot Size), the curves show the probability of being on a given intensity of sampling or Mandatory inspection at any point in time for all values of average process quality, p.

4.2 <u>Reference Code Numbers for Effectiveness Measure Charts</u>. In order to use Figure 6, it is necessary to know the Reference Code for the designated sampling system. This Code is found by entering Table V in the column for the designated AQL and in the row for the appropriate Lot size. AQL, AOQL, and Code are required in order to interpret Figure 6. These Codes range from 1-6 to 8-11 and refer to the different charts that comprise Figure 6.

4.3 <u>Average Fraction Inspected</u>. The value of the AFI when the process is operating at the designated AQL is tabulated for each system in Table III.

Since the value of the AFI changes as a function of the process average, it may be desirable to know the value of the AFI at process quality levels other than the AQL. This information is obtained from the appropriate Code chart in Figure 6. The values of 100p, the quality level points of interest

in terms of percent defective, are divided by the AQL. The AFI is read directly from the vertical axis of the chart for each value of p/AQL.

4.4 Average Outgoing Quality (AOQ). The Average Outgoing Quality Limit (AOQL) for each sampling system is tabulated at the bottom of all Tables. Frequently it is desirable to know the value of the AOQ at a number of values of 100p or to know the value of 100p at which the AOQ reaches it maximum, the AOQL. These values may be obtained from Figure 6 for all sampling systems. In order to use Figure 6, it is necessary to know the AQL, AOQL, and the Reference Code obtained from Table V.

4.4.1 The Value of 100p at Which the AOQ Reaches Maximum (AOQL). The value of 100p, in percent defective, at which the AOQL occurs is obtained by observing the point on the chart at which the AOQ curve reaches 1.0 and starts down again. The value of (100p/AQL) is read from the horizontal axis. This value is multiplied by the AQL to obtain the desired value of 100p.

4.4.2 Obtaining the AOQ Curve for a Specific Sampling System. The AOQ functions of Figure 6 are normalized on the horizontal axis by dividing the actual value of 100p by the AQL and normalized on the vertical axis by dividing the actual value of the AOQ by the AOQL. Thus, in order to draw a curve of AOQ for a specific sampling system, it is necessary to know the AQL, AOQL, and Reference Code (Table V) for the specific sampling system. For a range of values of 100p, divide 100p by the AQL. Locating the values of (100p/AQL) on the horizontal axis of the appropriate chart, read from the vertical axis the value of (AOQ/AOQL) for each point. Multiply this value of (AOQ/AOQL) by the AOQL for the specific sampling system to obtain the value of AOQ.

Procedures Summary

This summary describes the major steps in operating the sampling system and references the detailed instruction in Section 3.

I. Planning Data

1. Enter the required shop data on the DVR, Percent Defective Control Chart, and PDCC Data Summary as required.
2. Determine the Lot size and secure the shop AQL (para. 3.1.1).
3. Determine the Sample sizes from Table I.
4. Use the Table of Random Numbers (1-50), Table VI, to plan the order of sampling (para. 3.2).

II. Operating Data

1. Sample products in accordance with plan.
2. Record results on DVR and transfer daily (or at the completion of each subgroup when on Mandatory inspection) to the Percent Defective Control Chart Data Summary form (para. 3.4.1).
3. At the completion of each Lot Size sample (or subgroup when on Mandatory inspection), calculate the value of 100p and obtain the value of the control limit (CL) (para. 3.4.1).
4. Transfer the data found in (3) to the Percent Defective Control Chart and plot the values of 100p and CL on the chart (para. 3.4.3).
5. Using Figure 1 as a guide, determine the intensity of sampling (or Mandatory inspection) for the next lot (or subgroup). Enter this information on the Percent Defective Control Chart Data Summary form.
6. Significant actions, such as changes in inspection intensity (R,

N, T, M), explanations of points out-of-control on the PDCC, and the imposition of Mandatory inspection are to be noted on the MVR and PDCC, including cross-referencing of any corrective actions taken.

Table I Sample Sizes in Number of Items Under Reduced (NR), Normal (NN), Tightened (NT) Inspection.

LOT SIZE		ACCEPTABLE QUALITY LEVEL (AQL) in percent defective							
		0.40	0.65	1.0	1.5	2.5	4.0	6.5	10.0
0–125	NR							4	3
	NN	↓	↓	↓	↓	↓	↓	11	8
	NT							17	13
126–200	NR						7	5	4
	NN	↓	↓	↓	↓	↓	17	12	9
	NT						27	19	14
201–315	NR				10	11	8	7	5
	NN	↓	↓	↓	26	27	19	18	13
	NT				41	42	30	28	21
316–500	NR			20	17	12	11	9	7
	NN	↓	↓	50	42	30	28	24	18
	NT			79	67	48	44	38	28
501–800	NR		32	26	19	17	16	13	9
	NN	↓	79	66	48	43	40	32	22
	NT		126	105	76	69	63	51	35
801–1250	NR	56	42	30	27	25	20	14	11
	NN	141	105	76	69	63	51	35	29
	NT	224	166	120	109	100	81	55	46
1251–2000	NN	65	48	43	39	32	22	18	12
	NR	164	120	109	99	80	55	45	30
	NT	261	190	173	157	127	88	71	48
2001–3160	NN	76	69	62	50	40	28	22	14
	NR	190	173	157	126	99	71	54	36
	NT	302	274	248	200	157	113	86	57
3161–5000	NN	109	99	80	63	45	34	28	19
	NR	274	248	200	157	112	85	71	47
	NT	434	393	318	249	178	135	113	75
5001–8000	NN	155	126	99	71	55	45	32	21
	NR	390	316	249	178	139	112	81	54
	NT	617	501	395	282	220	178	129	86
Over 8000	NN	199	157	112	85	71	51	37	25
	NR	501	395	282	213	178	129	94	62
	NT	793	627	446	337	282	204	149	98
		0.65	1.0	1.5	2.5	4.0	6.5	10.0	15.0
		AVERAGE OUTGOING QUALITY LIMIT (AOQL) in percent defective							

↓ Proceed in direction of arrow until first plan is encountered.

TABLE II Control Limits under Reduced (CL_r), Normal (CL_n) and Tightened (CL_t) Inspection in Percent Defective.

LOT SIZE		ACCEPTABLE QUALITY LEVEL (AQL) in percent defective							
		0.40	0.65	1.0	1.5	2.5	4.0	6.5	10.0
0-	CL_r	↓	↓	↓	↓	↓	↓	10.2	8.5
	CL_n							37.5	50.0
125	CL_t							22.7	31.2
126-	CL_r	↓	↓	↓	↓	↓	21.4	30.0	37.5
	CL_n						14.7	20.8	27.7
200	CL_t						13.0	18.4	25.0
201-	CL_r	↓	↓	↓	15.0	13.6	18.7	21.4	30.0
	CL_n				5.8	9.3	13.2	19.4	26.9
315	CL_t				6.1	8.3	11.7	16.1	26.2
316-	CL_r	↓	↓	7.5	8.8	12.5	13.6	27.8	35.7
	CL_n			5.0	5.9	8.3	12.5	18.7	25.0
500	CL_t			3.1	5.2	7.3	10.2	14.5	23.2
501-	CL_r	↓	4.7	5.8	7.9	8.8	15.6	19.2	27.8
	CL_n		3.2	3.8	5.2	8.1	11.2	17.2	25.0
800	CL_t		2.0	3.3	4.6	6.5	10.3	14.7	21.4
801-	CL_r	2.7	3.6	5.0	5.6	10.0	12.5	17.8	31.8
	CL_n	1.8	2.4	3.3	5.1	7.1	10.8	15.7	22.4
1250	CL_t	1.6	2.1	2.9	4.1	6.5	9.2	13.6	20.6
1251-	CL_r	2.3	3.1	3.5	6.4	7.8	11.4	19.4	29.2
	CL_n	1.5	2.1	3.2	4.5	6.9	10.0	14.4	21.2
2000	CL_t	1.3	1.8	2.6	4.1	5.9	8.5	13.4	19.8
2001-	CL_r	2.0	2.2	4.0	5.0	8.7	12.5	15.9	25.0
	CL_n	1.3	2.0	2.9	4.4	6.6	9.1	13.9	20.8
3160	CL_t	1.1	1.6	2.6	3.7	5.4	8.4	12.2	18.4
3161-	CL_r	1.4	2.5	3.1	5.6	7.8	10.3	16.1	23.6
	CL_n	1.3	1.8	2.7	4.1	5.8	8.8	13.4	20.0
5000	CL_t	1.0	1.6	2.3	3.4	5.3	7.8	11.9	18.0
5001-	CL_r	1.6	2.0	3.5	4.9	8.2	10.0	17.2	26.2
	CL_n	1.1	1.7	2.6	3.6	5.4	8.5	13.0	19.4
8000	CL_t	1.0	1.5	2.1	3.4	5.2	7.6	11.2	16.8
Over	CL_r	1.2	2.2	3.1	5.3	6.3	10.8	14.9	22.0
	CL_n	1.1	1.6	2.3	3.5	5.3	8.1	12.2	18.5
8000	CL_t	0.9	1.3	2.1	3.1	4.8	7.1	11.0	16.8
		0.65	1.0	1.5	2.5	4.0	6.5	10.0	15.0
		AVERAGE OUTGOING QUALITY LIMIT (AOQL) in percent defective							

↓ Proceed in direction of arrow until first plan is encountered.

TABLE III Average Fraction Inspected (AFI) at the Acceptable Quality Level (AQL) in Percent.

LOT SIZE	ACCEPTABLE QUALITY LEVEL (AQL) in percent defective							
	0.40	0.65	1.0	1.5	2.5	4.0	6.5	10.0
0-125	↓	↓	↓	↓	↓	↓	15.7	23.8
126-200	↓	↓	↓	↓	↓	10.5	7.8	7.1
201-315	↓	↓	↓	8.7	10.5	8.8	8.8	6.5
316-500	↓	↓	11.2	10.7	9.08	8.3	5.2	5.2
501-800	↓	11.4	10.7	8.9	8.5	6.2	4.9	3.8
801-1250	14.6	10.7	9.1	8.6	6.5	5.2	3.9	3.0
1251-2000	10.5	9.1	8.6	6.4	5.1	4.0	3.0	2.0
2001-3160	9.2	8.7	6.5	5.2	4.2	3.1	2.4	1.7
3161-5000	8.7	6.5	5.2	4.2	3.1	2.3	1.8	1.3
5001-8000	6.3	5.8	4.2	3.1	2.0	1.8	1.0	0.7
Over 8000	5.7	4.3	3.2	1.8	1.8	1.0	1.0	0.7
	0.65	1.0	1.5	2.5	4.0	6.5	10.0	15.0
	AVERAGE OUTGOING QUALITY LIMIT (AOQL) in percent defective							

↓ Proceed in direction of arrow until first plan is encountered.

TABLE IV Limiting Quality (LQ) in Percent Defective

LOT SIZE	ACCEPTABLE QUALITY LEVEL (AQL) in percent defective							
	0.40	0.65	1.0	1.5	2.5	4.0	6.5	10.0
0-125	↓	↓	↓	↓	↓	↓	28.1	40.5
126-200	↓	↓	↓	↓	↓	17.1	26.5	37.0
201-315	↓	↓	↓	7.5	11.2	16.7	23.7	32.0
316-500	↓	↓	5.7	7.1	10.2	15.1	22.4	31.0
501-800	↓	3.5	4.5	6.6	9.5	13.3	19.9	29.0
801-1250	2.0	2.9	4.1	6.1	8.5	12.7	19.2	27.0
1251-2000	1.8	2.6	3.8	5.4	8.0	11.9	17.0	26.0
2001-3160	1.6	2.4	3.4	5.1	7.7	10.9	16.4	25.0
3161-5000	1.5	2.1	3.2	4.8	7.0	10.7	15.77	24.0
5001-8000	1.4	2.0	3.0	4.4	6.5	10.1	15.5	23.5
Over 8000	1.3	1.9	2.8	4.3	6.4	9.7	14.8	22.5
	0.65	1.0	1.5	2.5	4.0	6.5	10.0	15.0
	AVERAGE OUTGOING QUALITY LIMIT (AOQL) in percent defective							

↓ Proceed in direction of arrow until first plan is encountered.

TABLE V Reference Codes to Operating Characteristic (OC) Curves of Figure 6.

LOT SIZE	ACCEPTABLE QUALITY LEVEL (AQL) in percent defective							
	0.40	0.65	1.0	1.5	2.5	4.0	6.5	10.0
0-125	↓	↓	↓	↓	↓	↓	1-7	1-8
126-200	↓	↓	↓	↓	↓	2-6	2-7	2-8
201-315	↓	↓	↓	3-4	3-5	3-6	3-7	3-8
316-500	↓	↓	4-3	4-4	4-5	4-6	4-7	4-8
501-800	↓	5-2	5-3	5-4	5-5	5-6	5-7	5-8
801-1250	6-1	6-2	6-3	6-4	6-5	6-6	6-7	6-8
1251-2000	7-1	7-2	7-3	7-4	7-5	7-6	7-7	7-8
2001-3160	8-1	8-2	8-3	8-4	8-5	8-6	8-7	8-8
3161-5000	9-1	9-2	9-3	9-4	9-5	9-6	9-7	9-8
5001-8000	10-1	10-2	10-3	10-4	10-5	10-6	10-7	10-8
Over 8000	11-1	11-2	11-3	11-4	11-5	11-6	11-7	11-8
	0.65	1.0	1.5	2.5	4.0	6.5	10.0	15.0
	AVERAGE OUTGOING QUALITY LIMIT (AOQL) in percent defective							

↓ Proceed in direction of arrow until first plan is encountered.

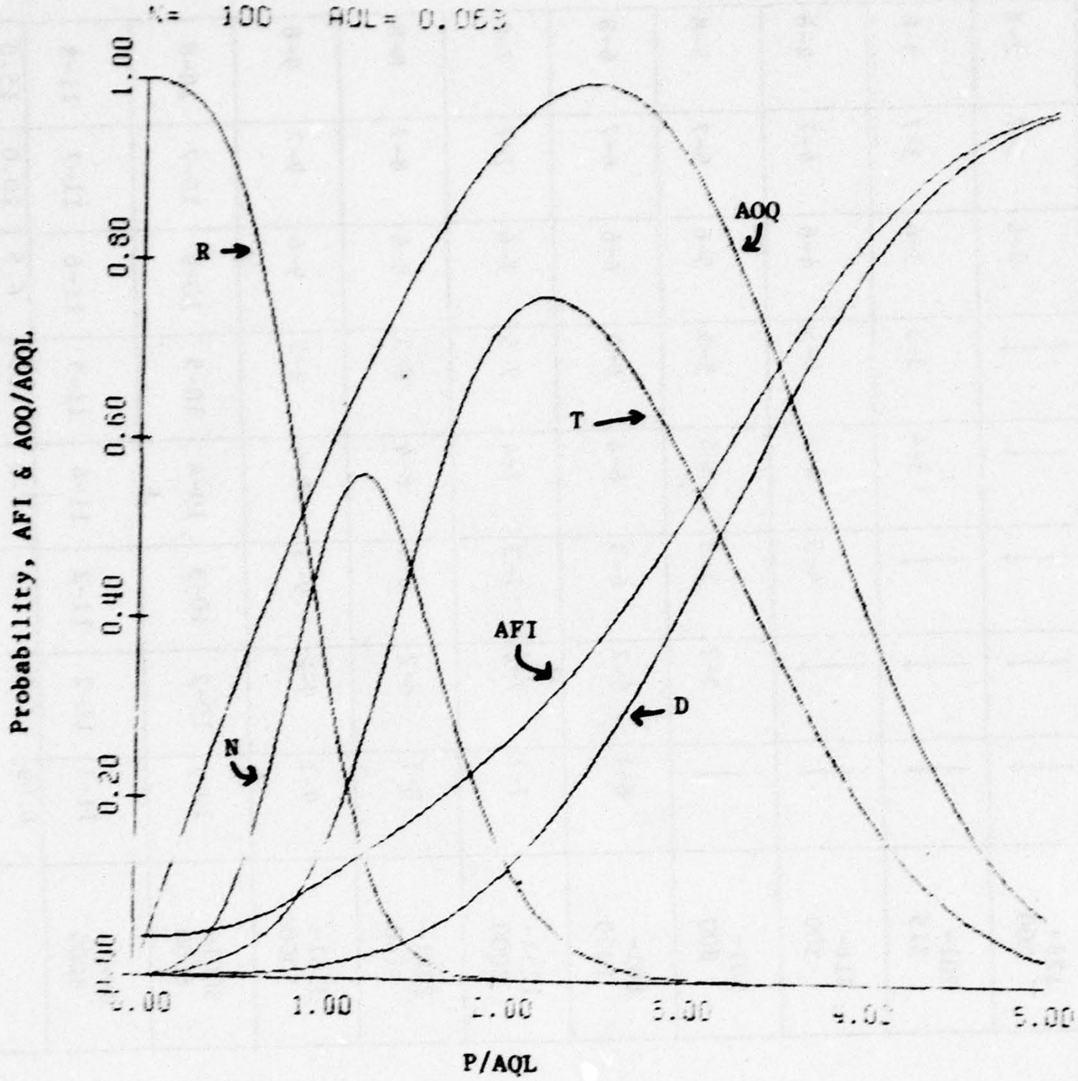


Figure 6: Operating Characteristic Curves

Code 1-7

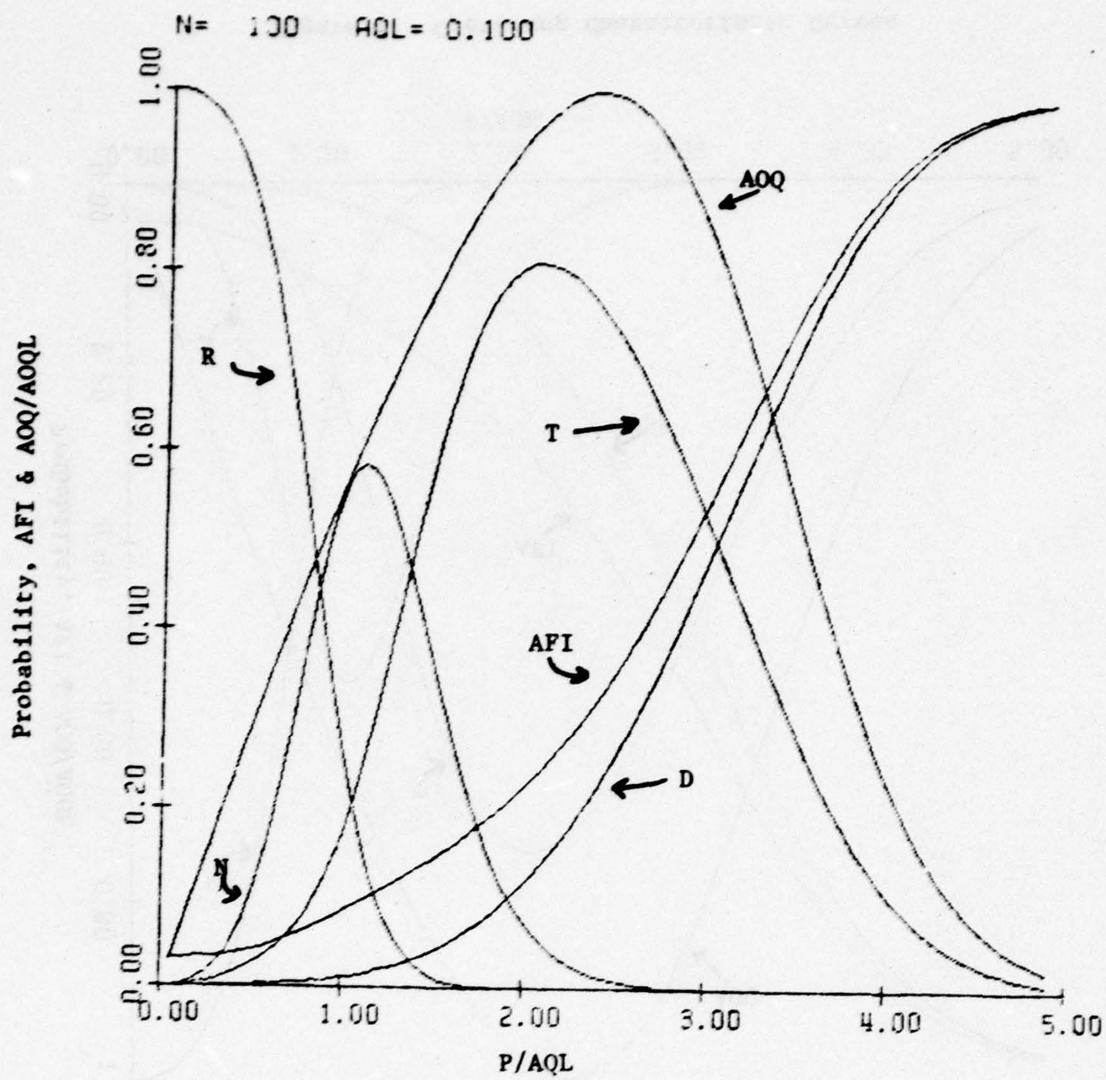


Figure 6: Operating Characteristic Curves

Code 1-8

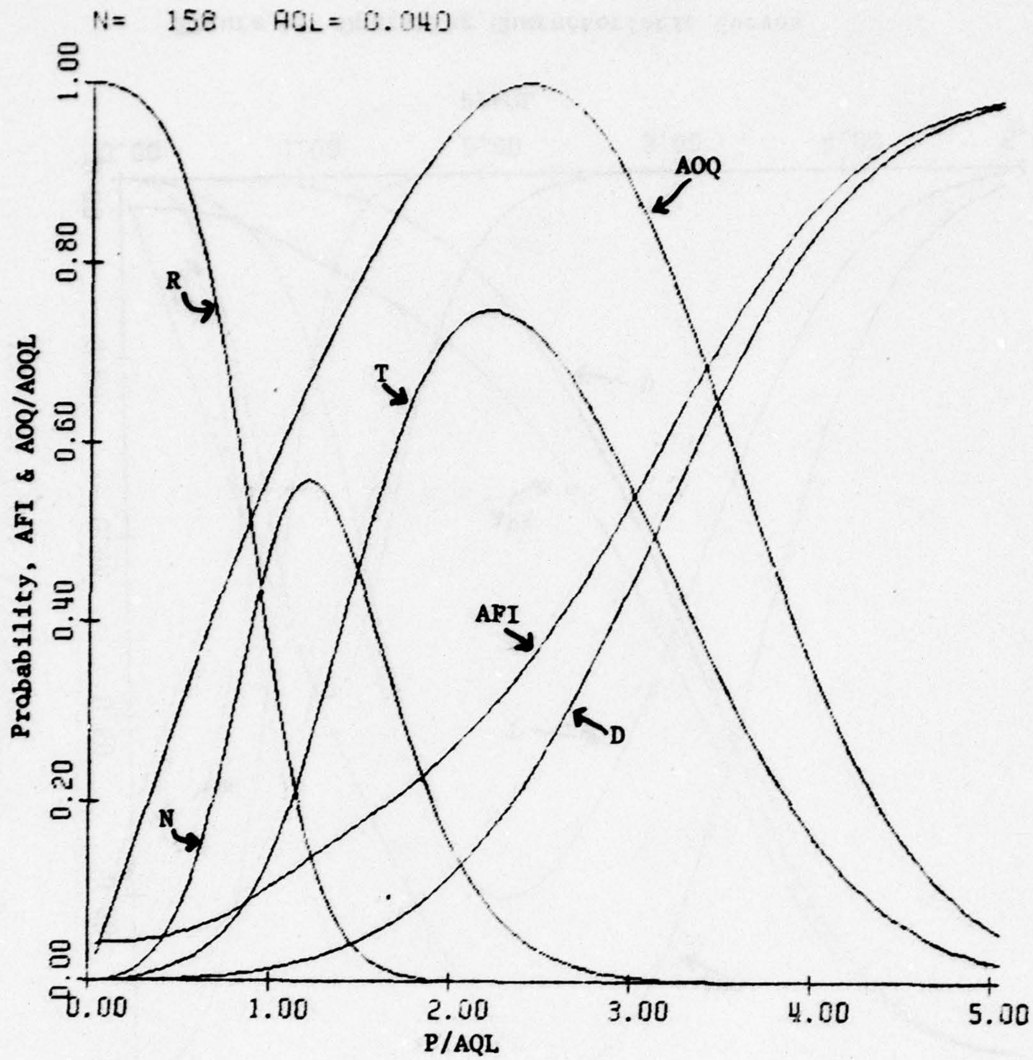


Figure 6: Operating Characteristic Curves

Code 2-6

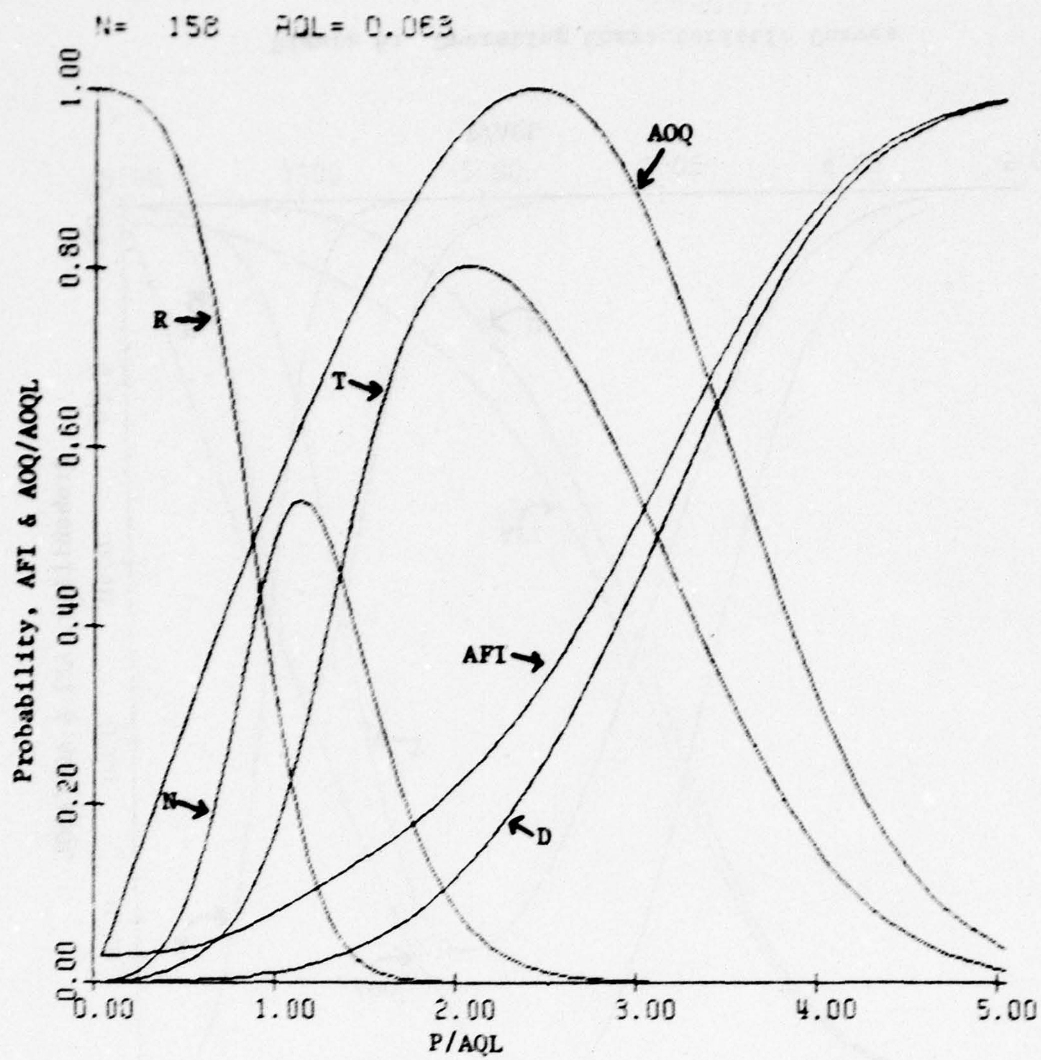


Figure 6: Operating Characteristic Curves

Code 2-7

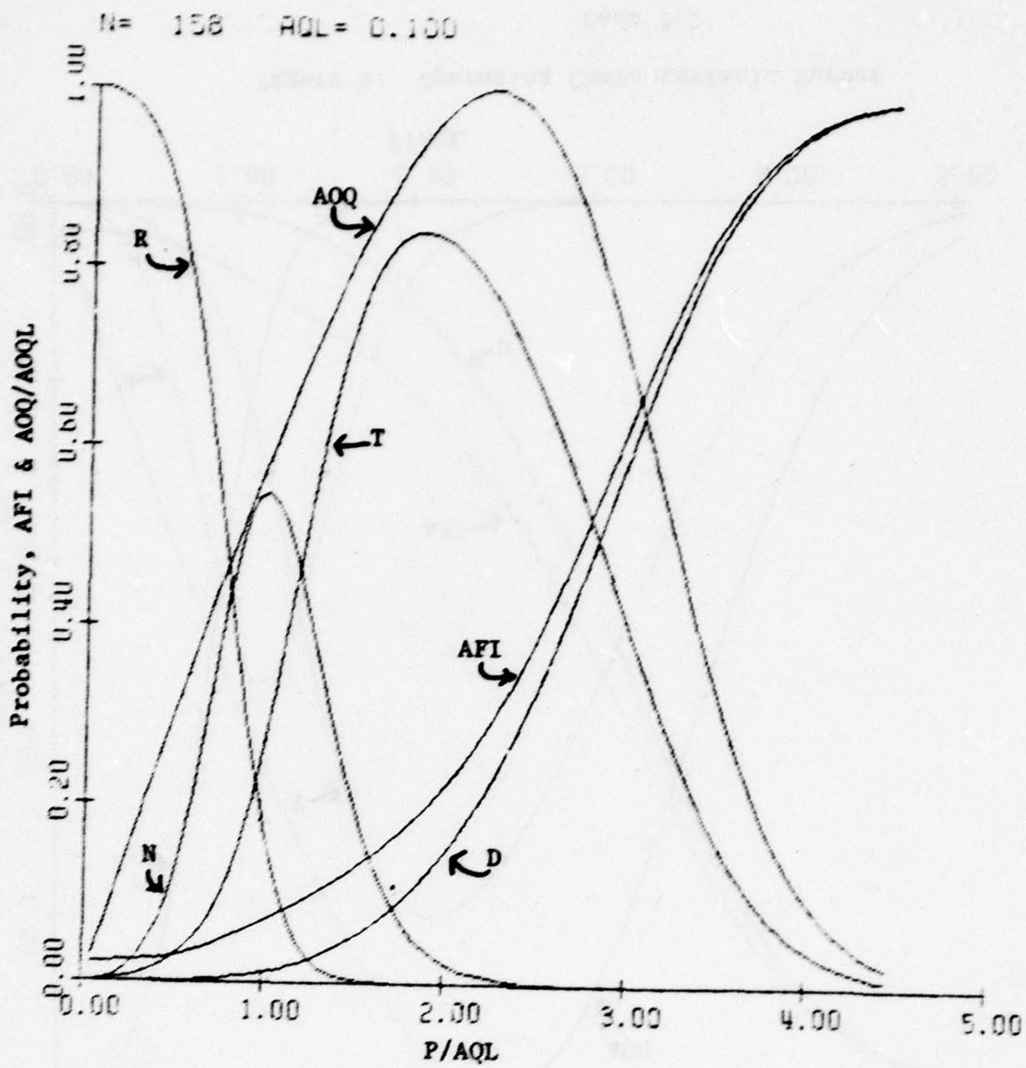


Figure 6: Operating Characteristic Curves

Code 2-8

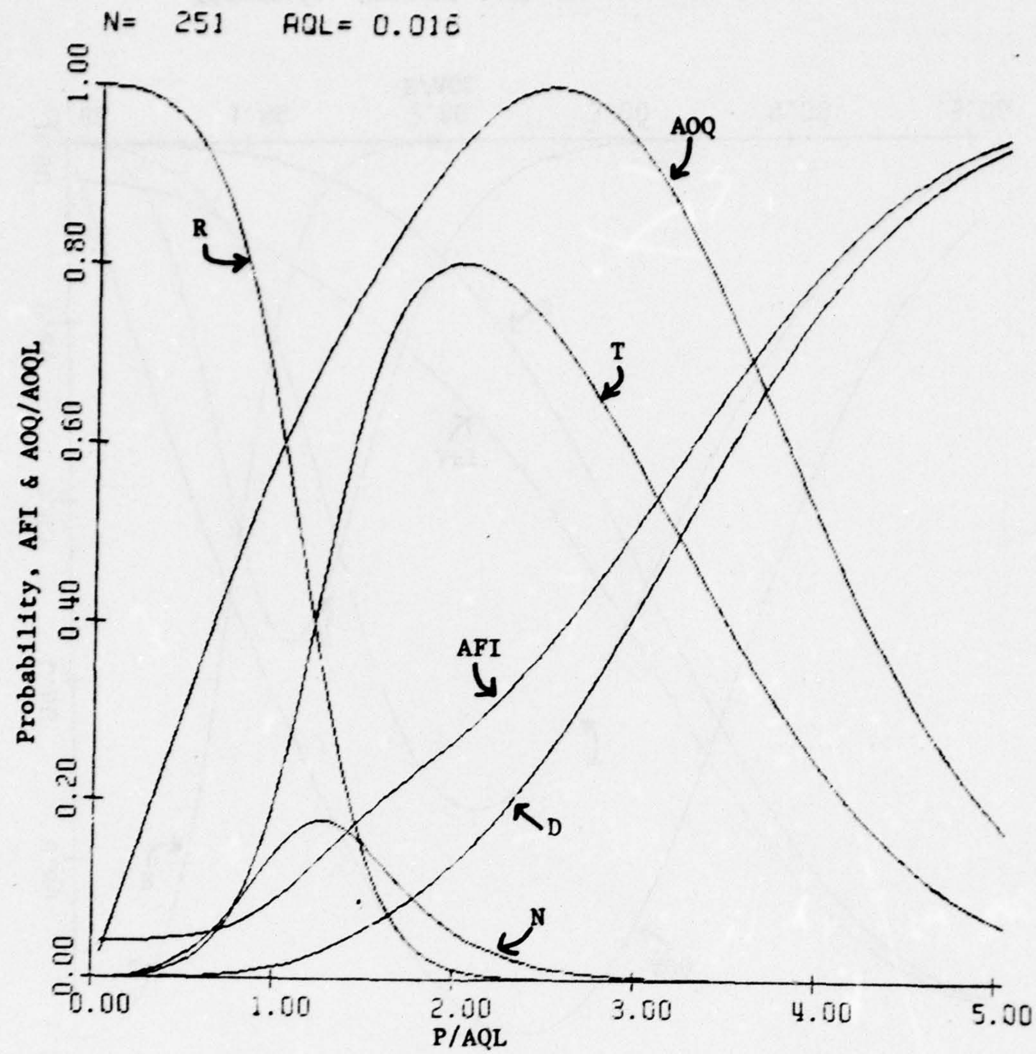


Figure 6: Operating Characteristic Curves

Code 3-4

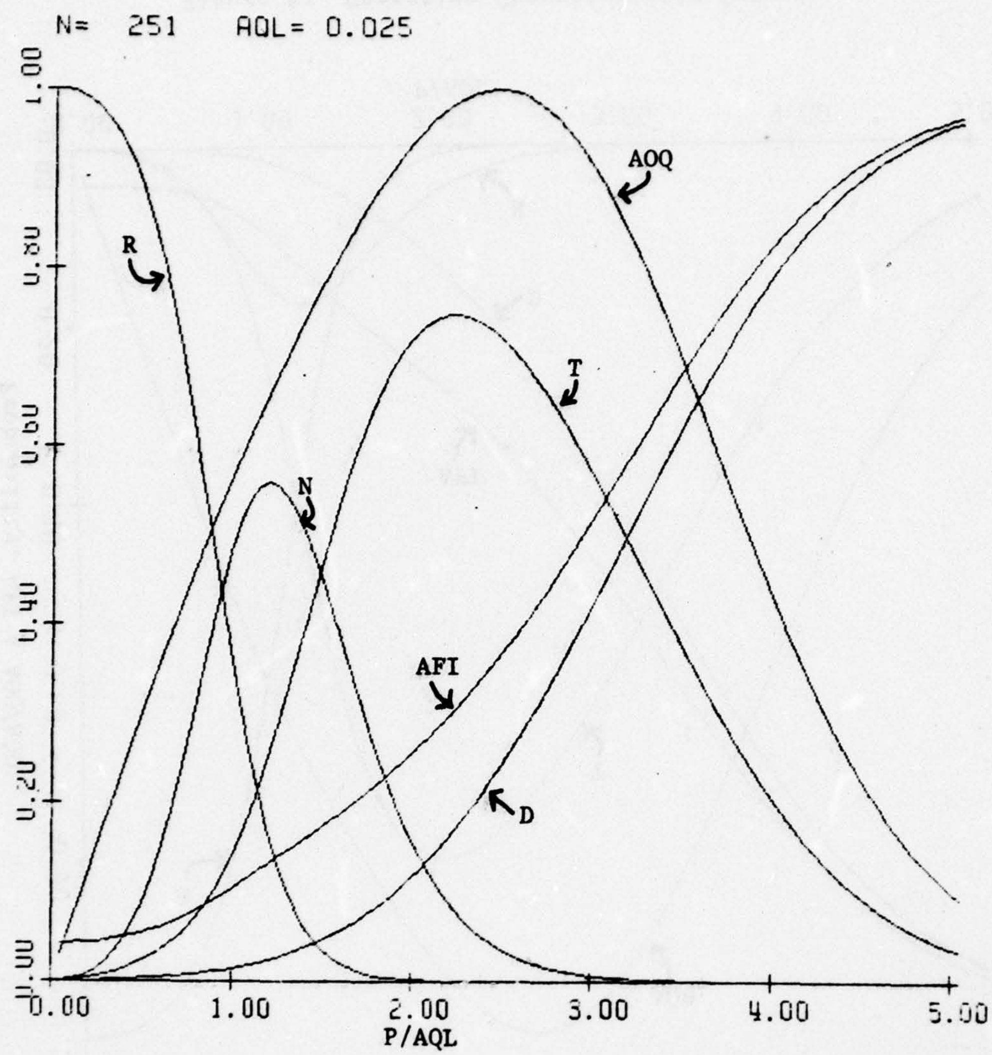


Figure 6: Operating Characteristic Curves

Code 3-5

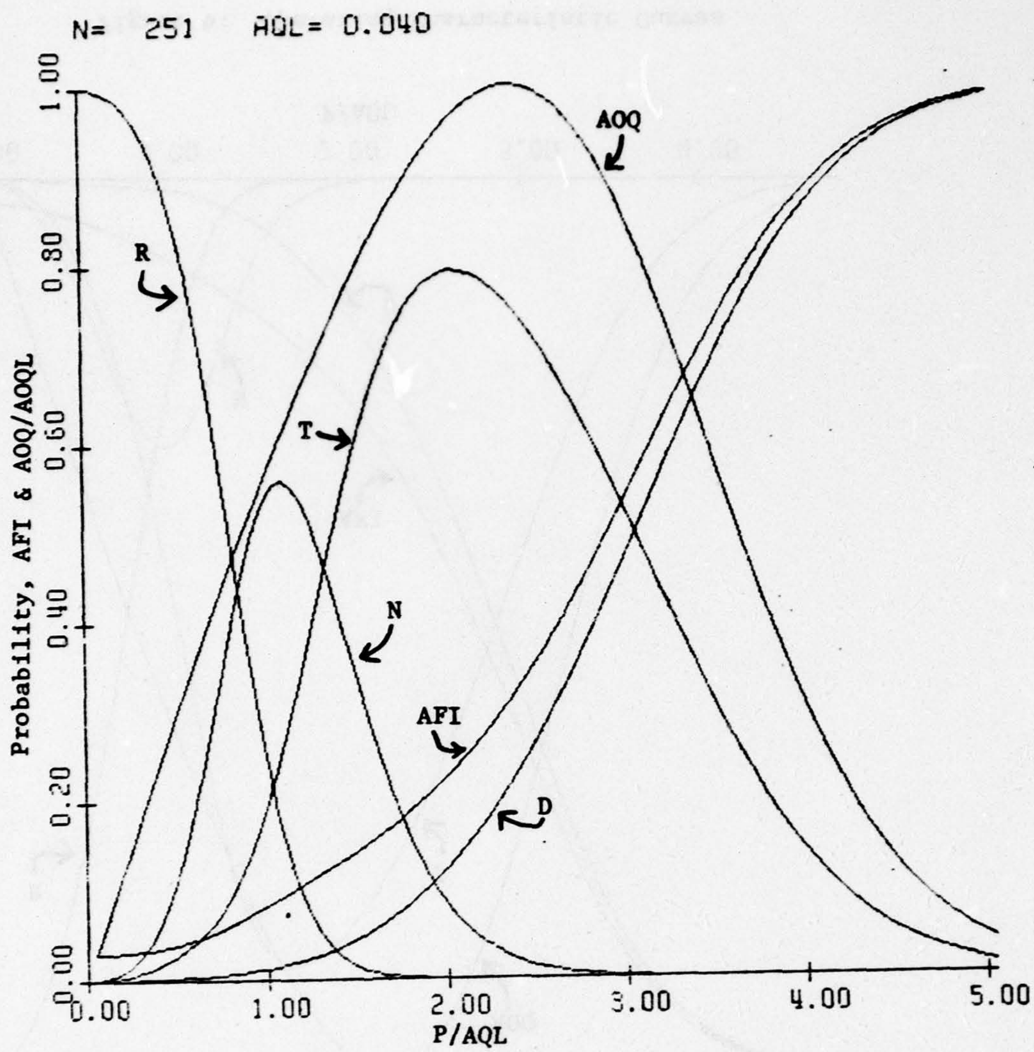


Figure 6: Operating Characteristic Curves

Code 3-6

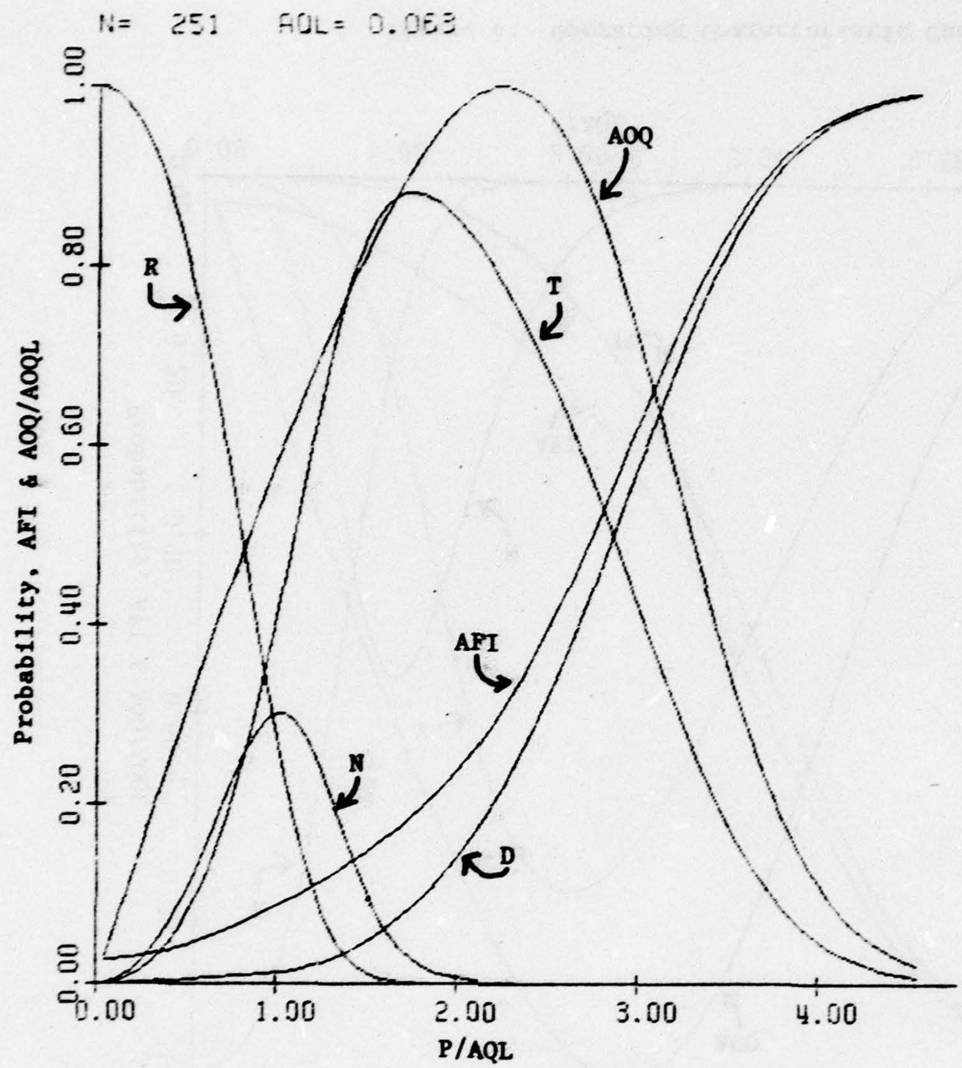


Figure 6: Operating Characteristic Curves

Code 3-7

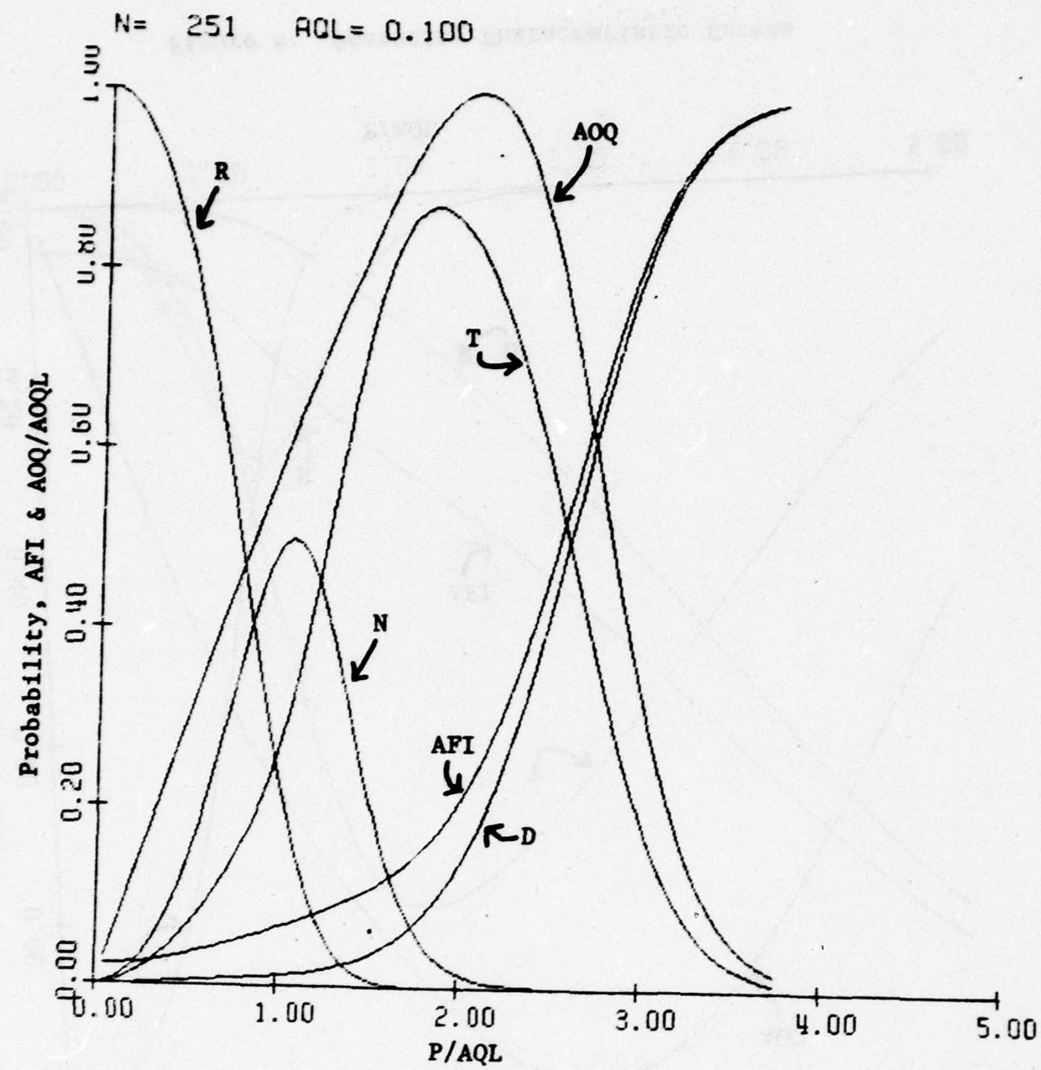


Figure 6: Operating Characteristic Curves

Code 3-8

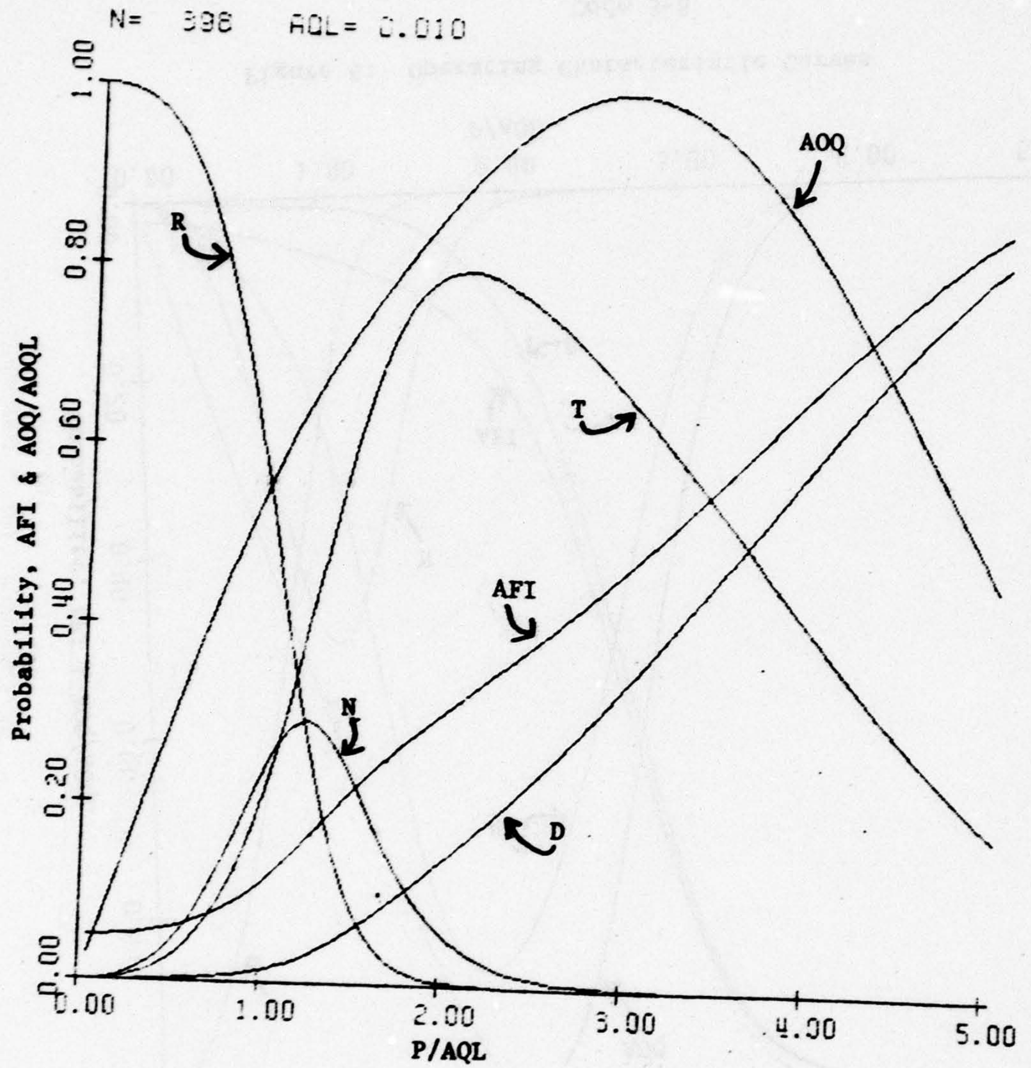


Figure 6: Operating Characteristic Curves

Code 4-3

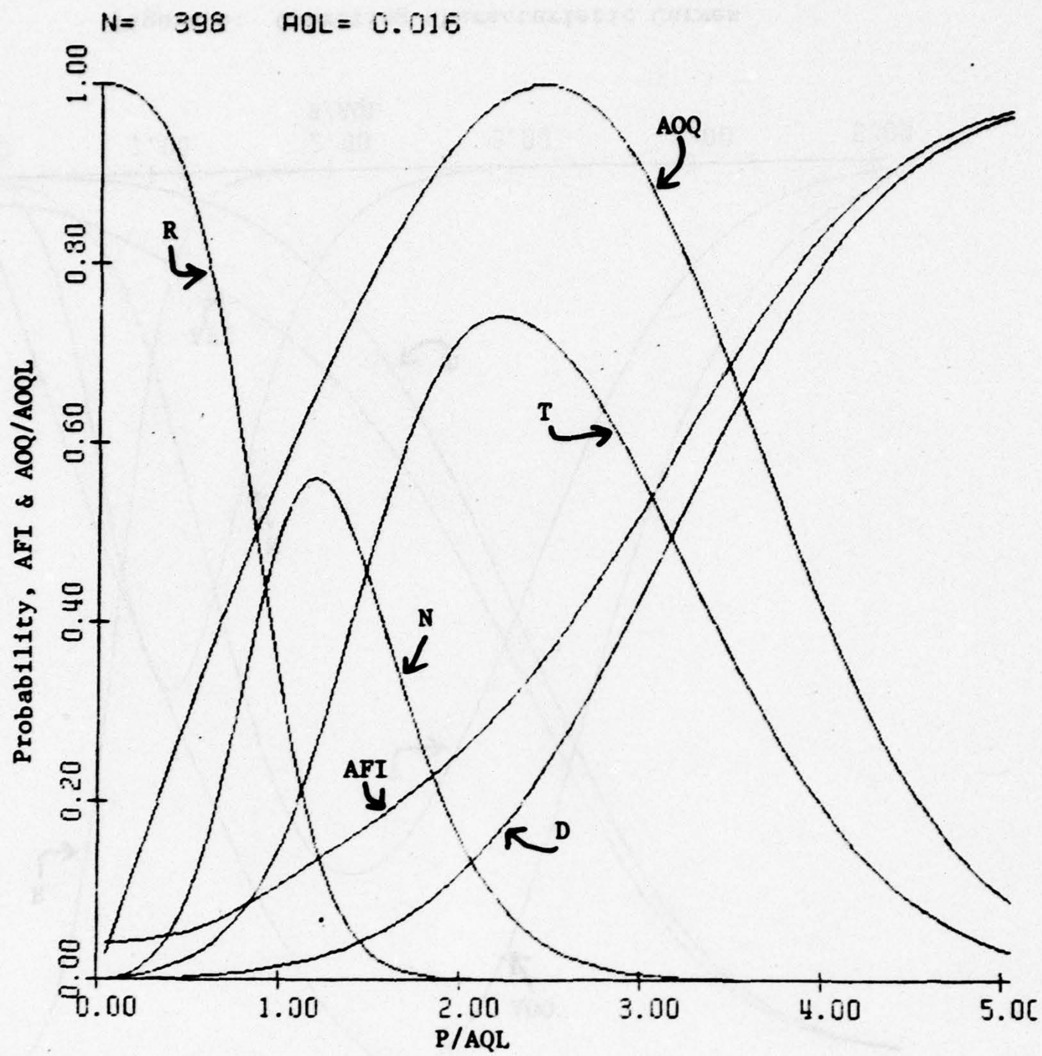


Figure 6: Operating Characteristic Curves

Code 4-4

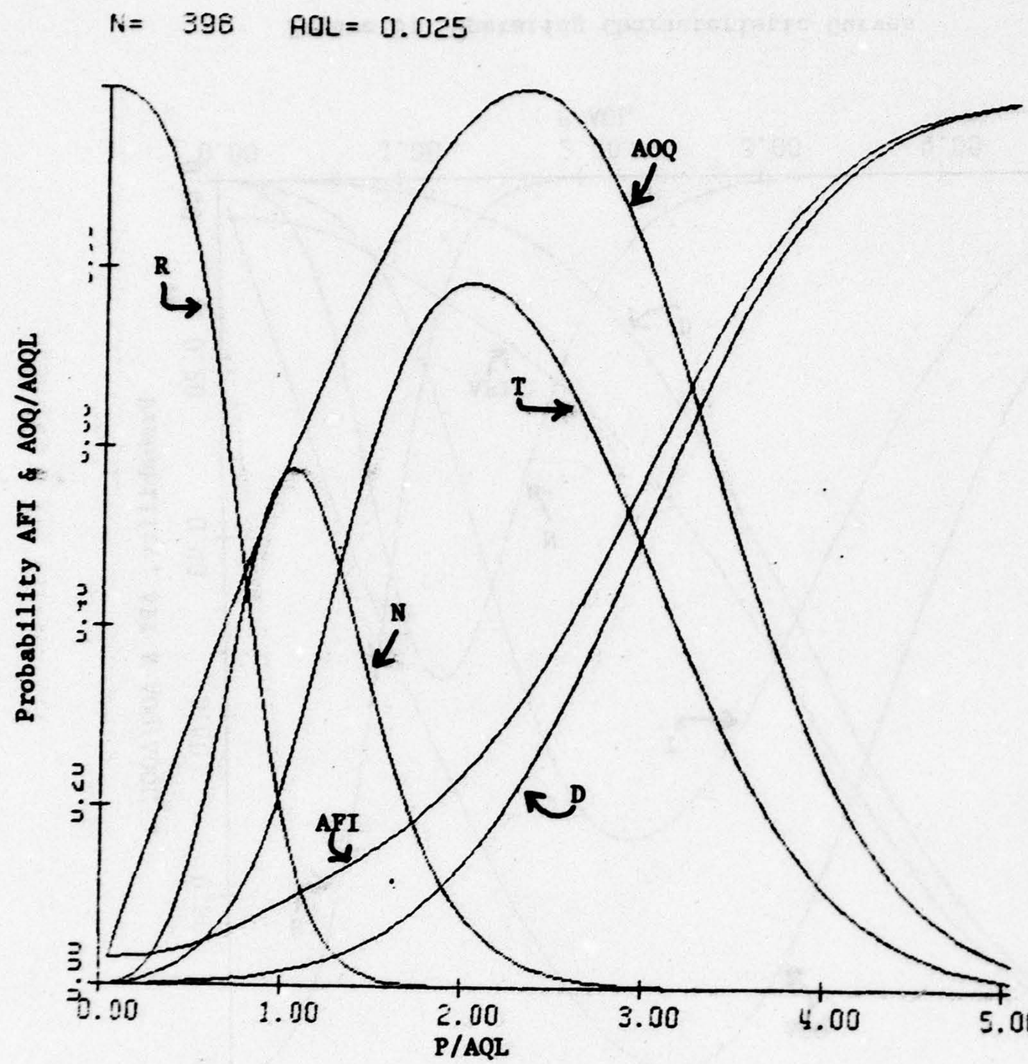


Figure 6: Operating Characteristic Curves

Code 4-5

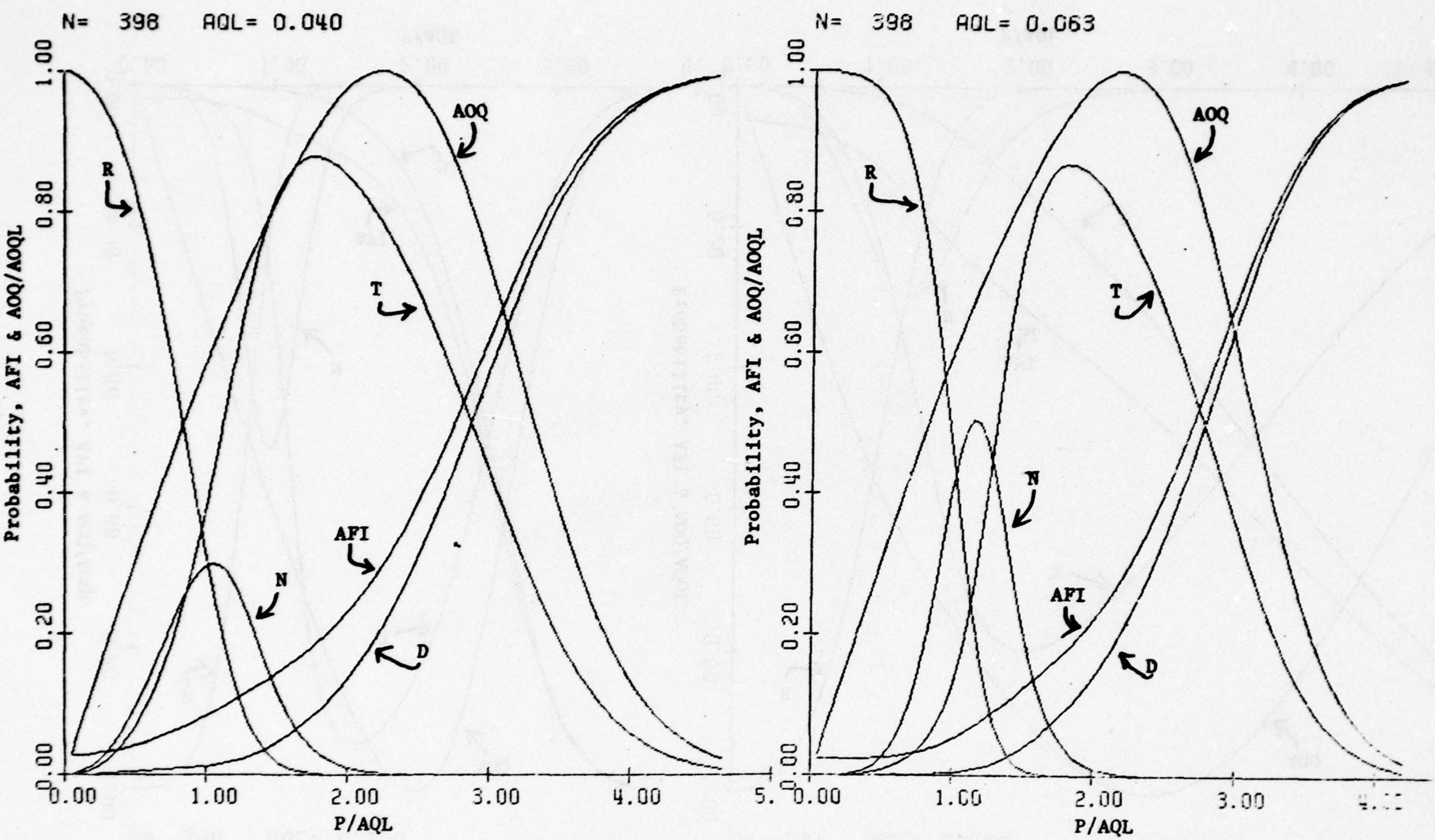


Figure 6: Operating Characteristic Curves

Code 4-6 and 4-7

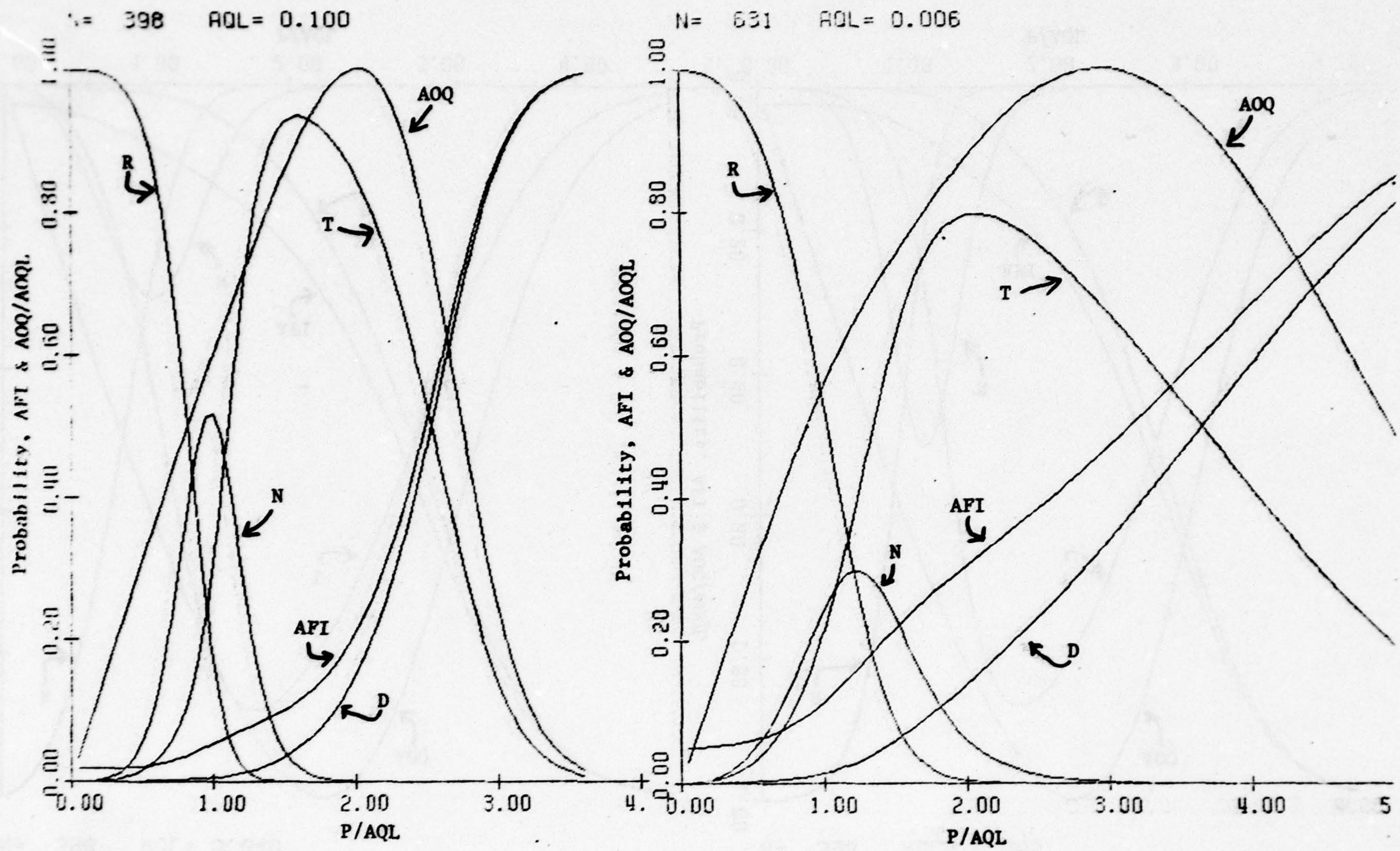


Figure 6: Operating Characteristic Curves

Code 4-8 and 5-2

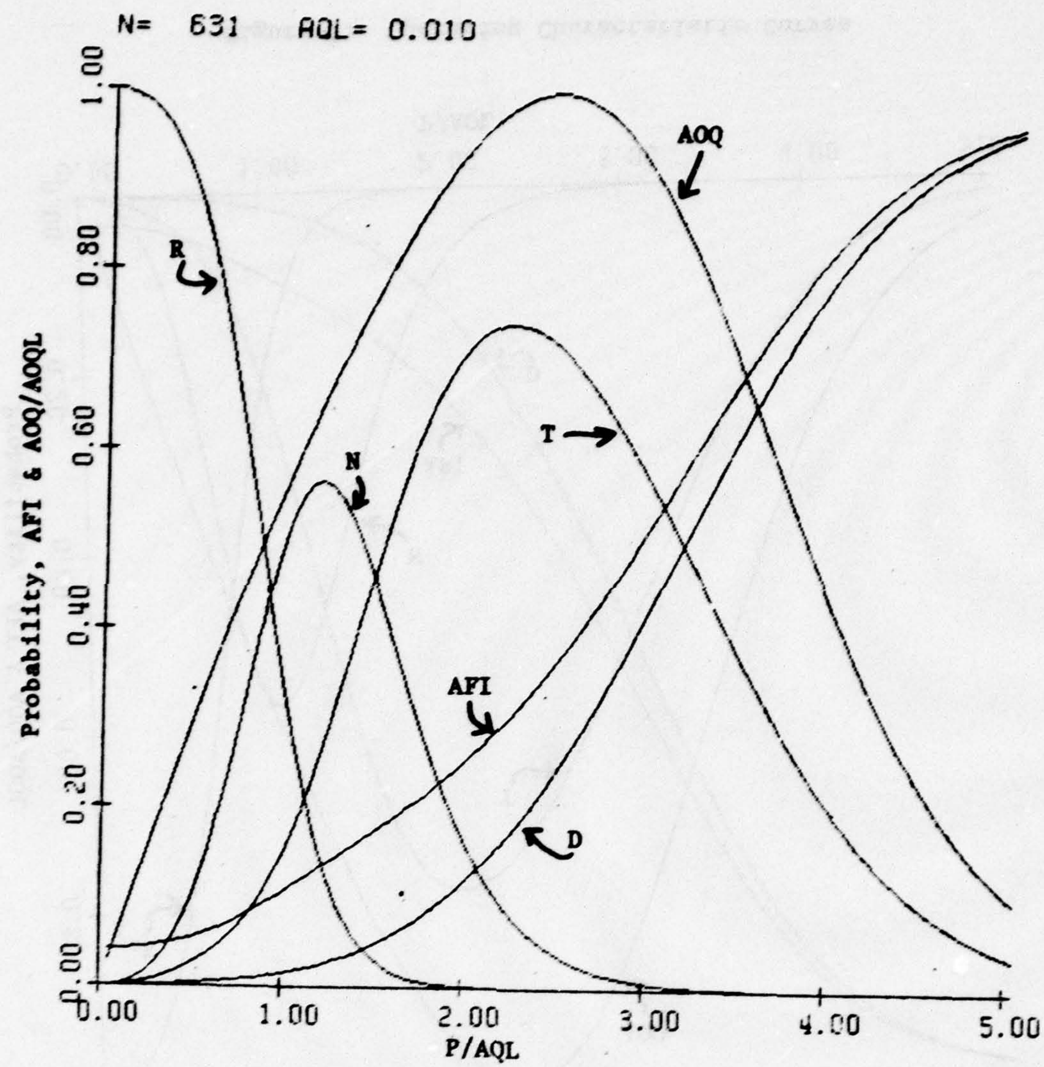


Figure 6: Operating Characteristic Curves

Code 5-3

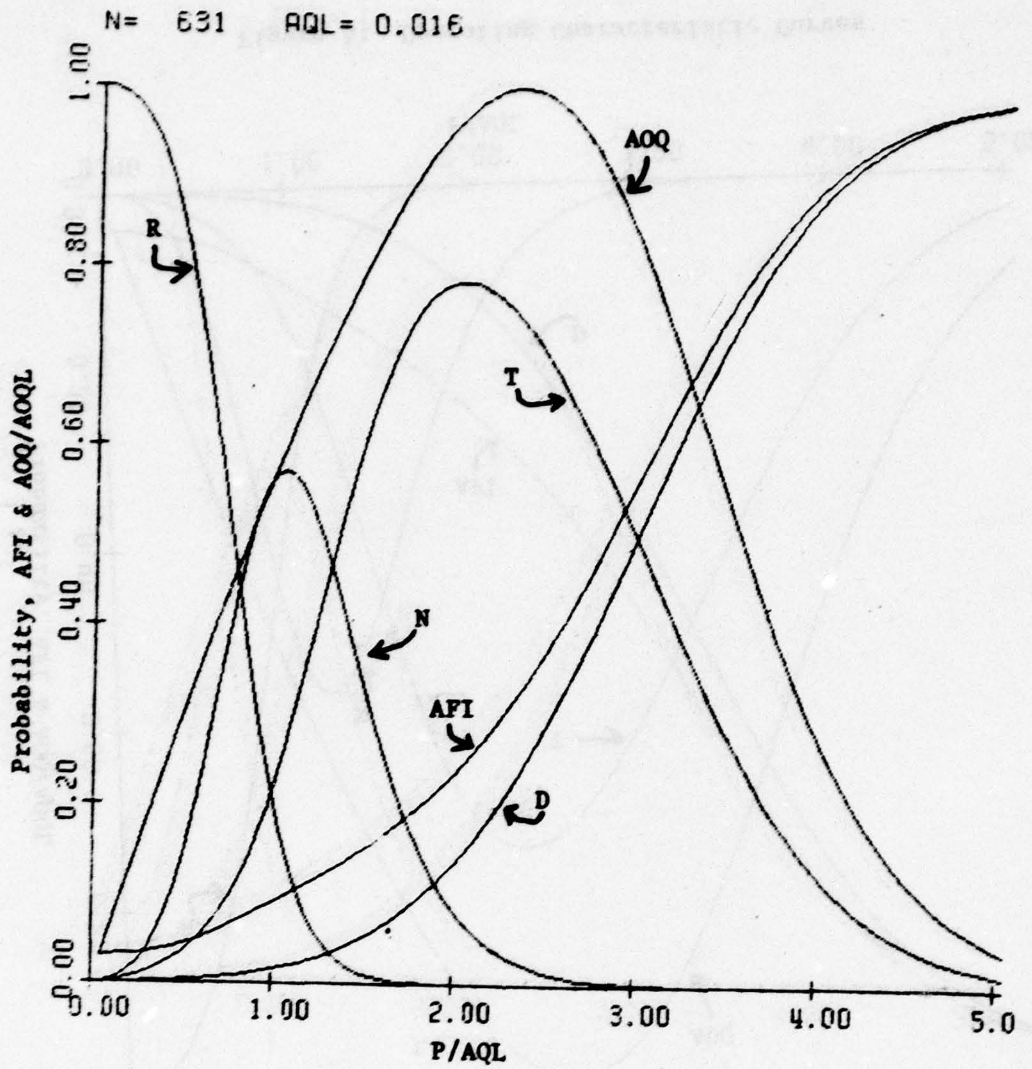


Figure 6: Operaring Characteristic Curves

Code 5-4

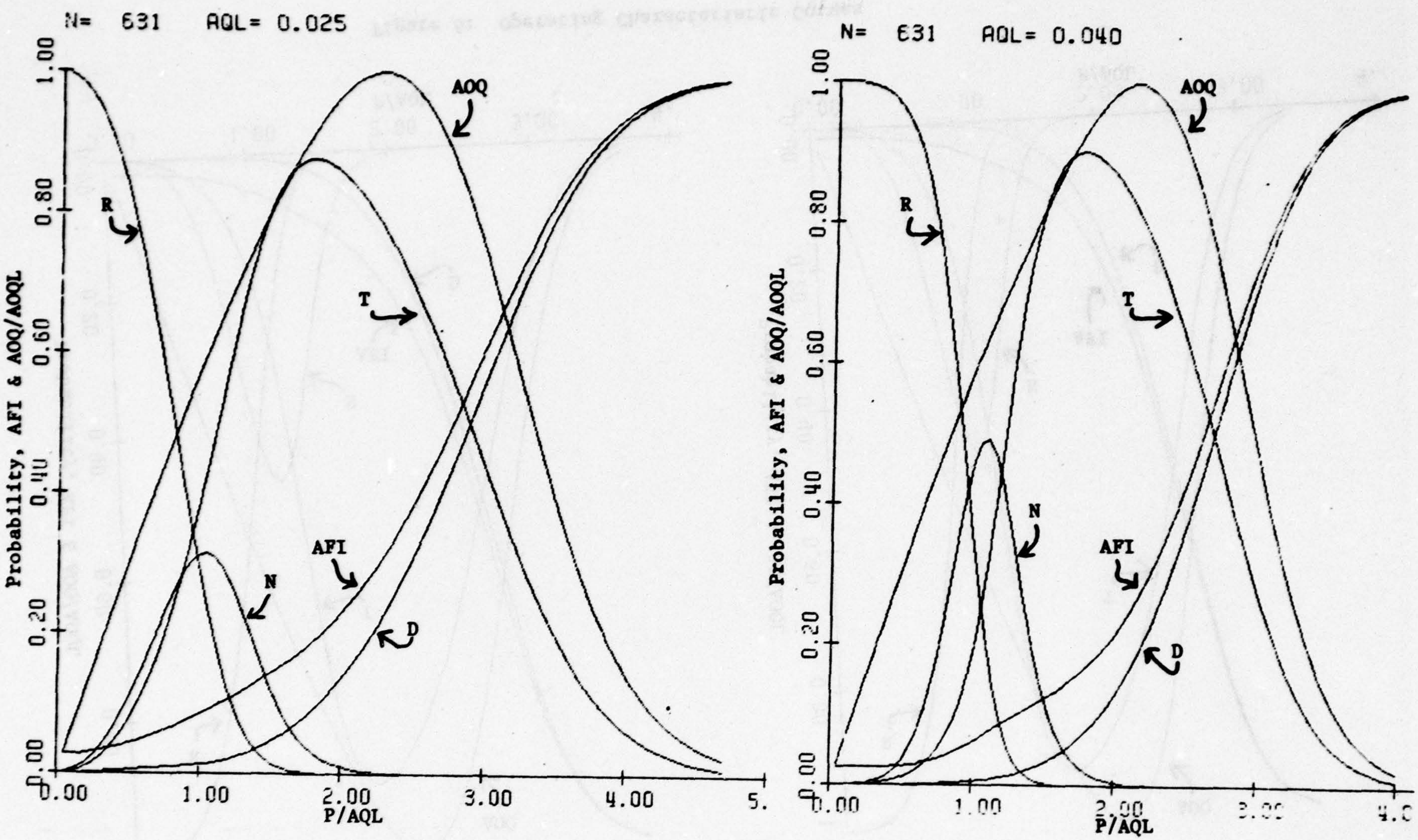


Figure 6: Operating Characteristic Curves

Code 5-5 and 5-6

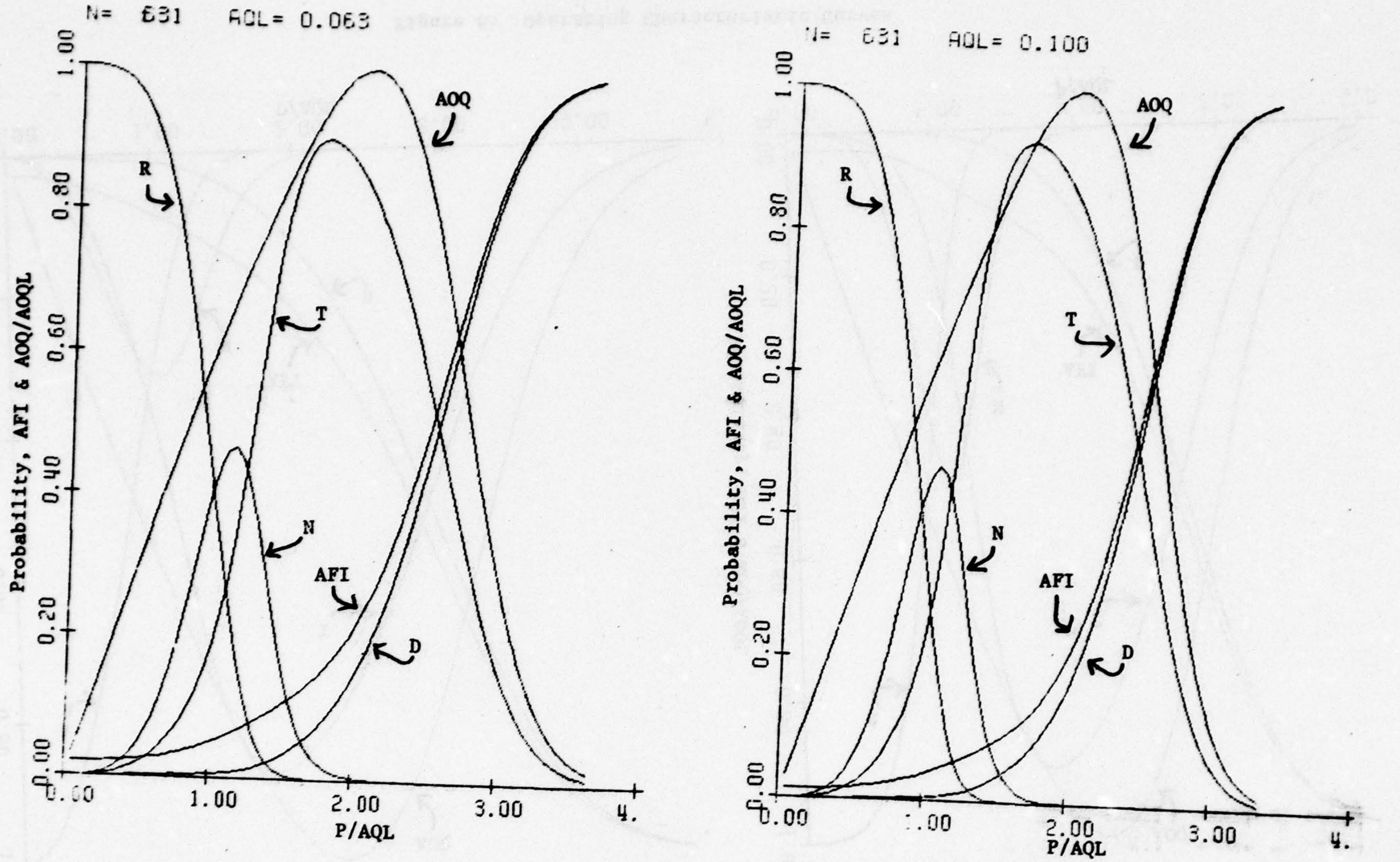


Figure 6: Operating Characteristic Curves

Code 5-7 and 5-8

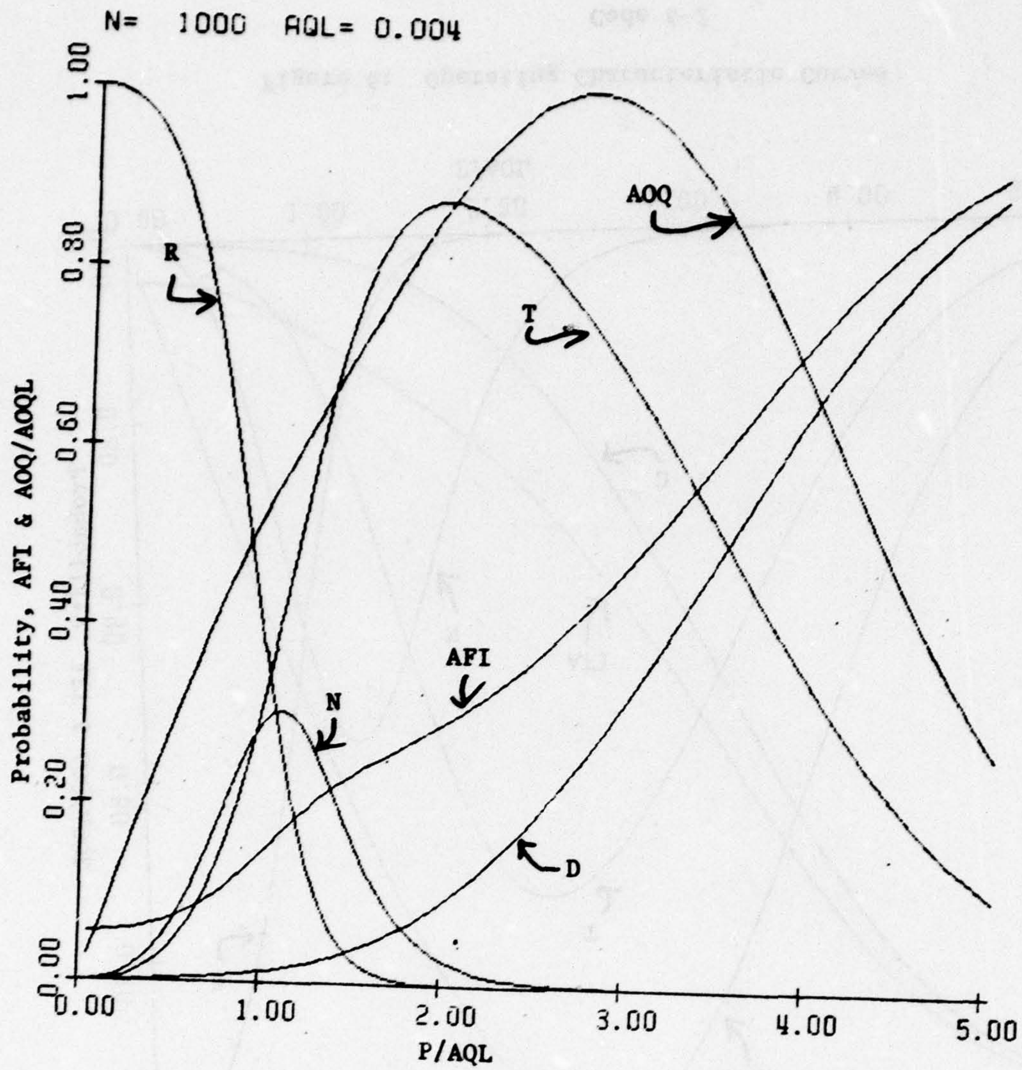


Figure 6: Operating Characteristic Curves

Code 6-1

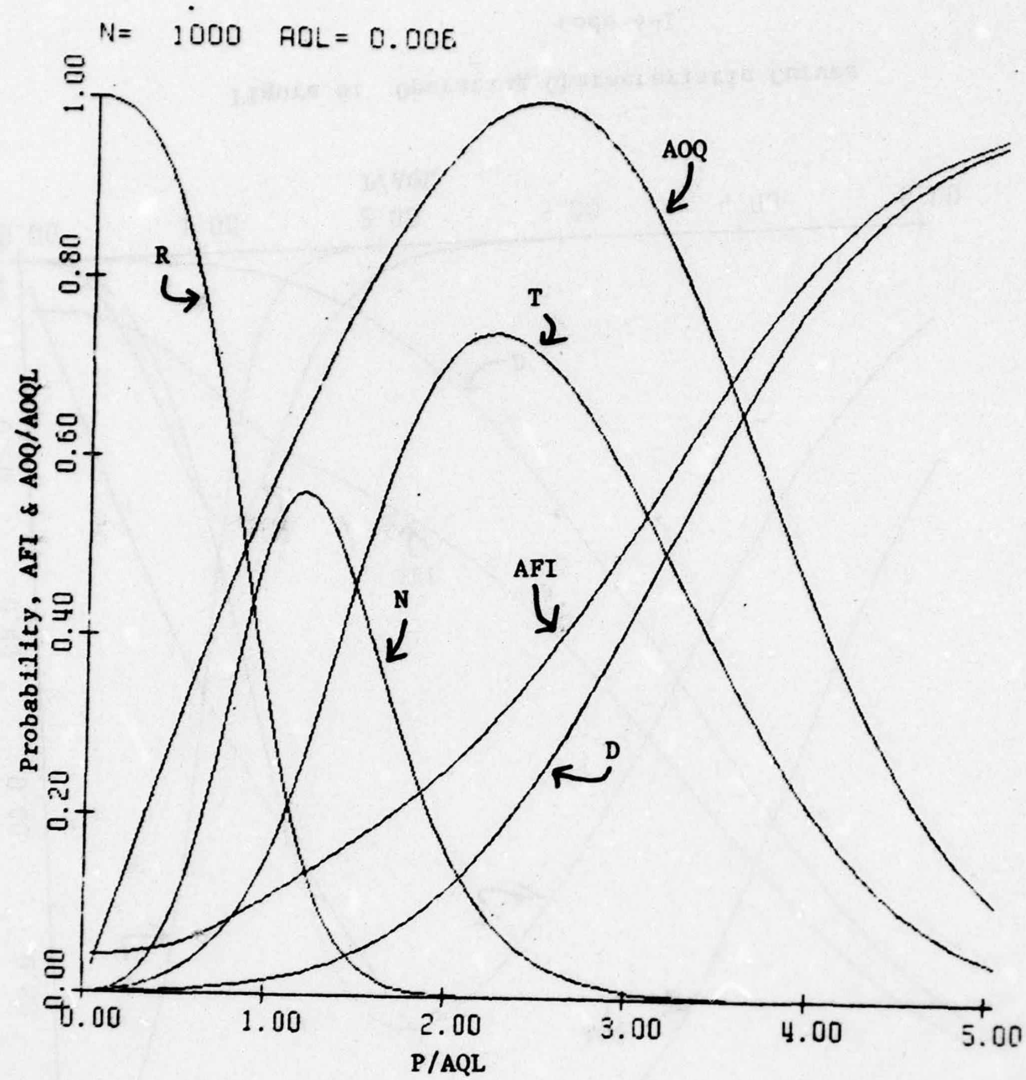


Figure 6: Operating Characteristic Curves

Code 6-2

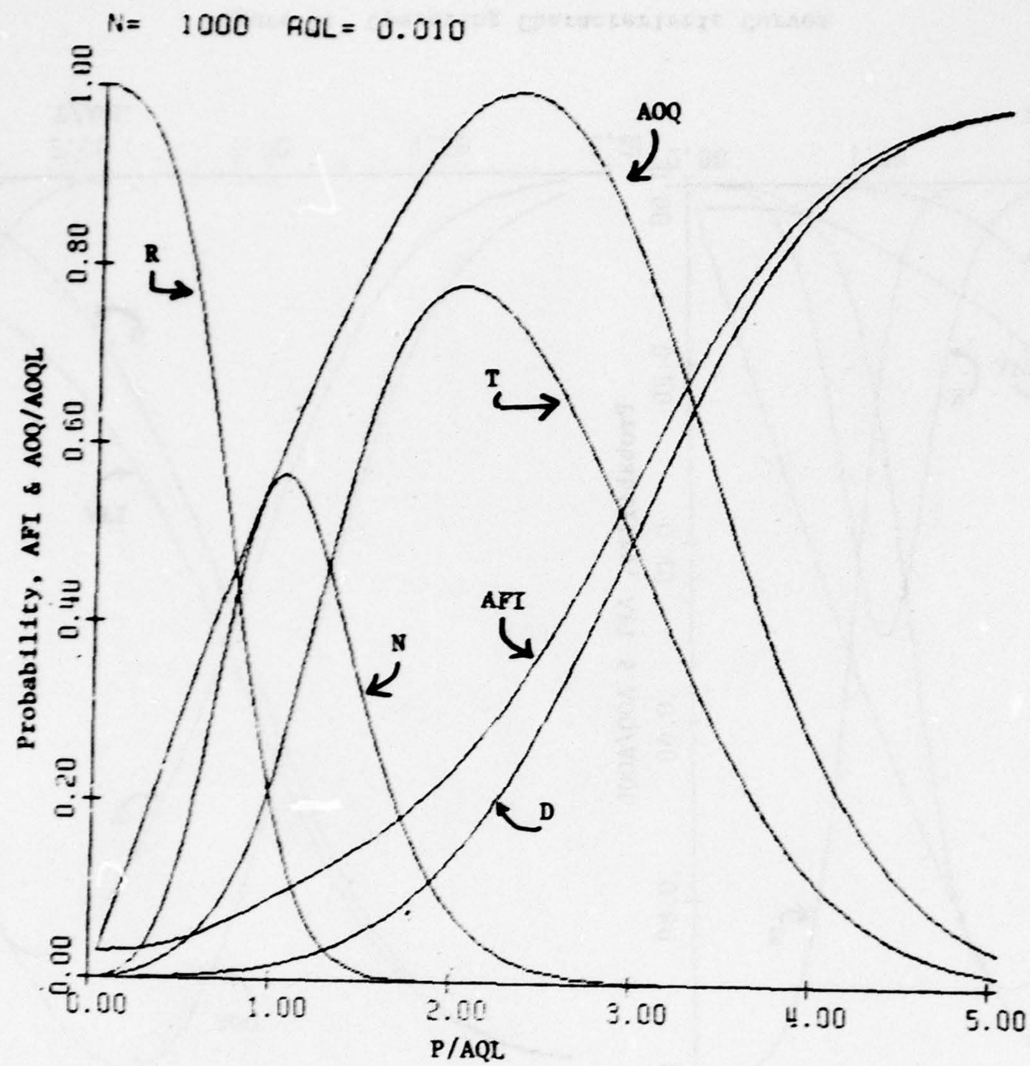


Figure 6: Operating Characteristic Curves

Code 6-3

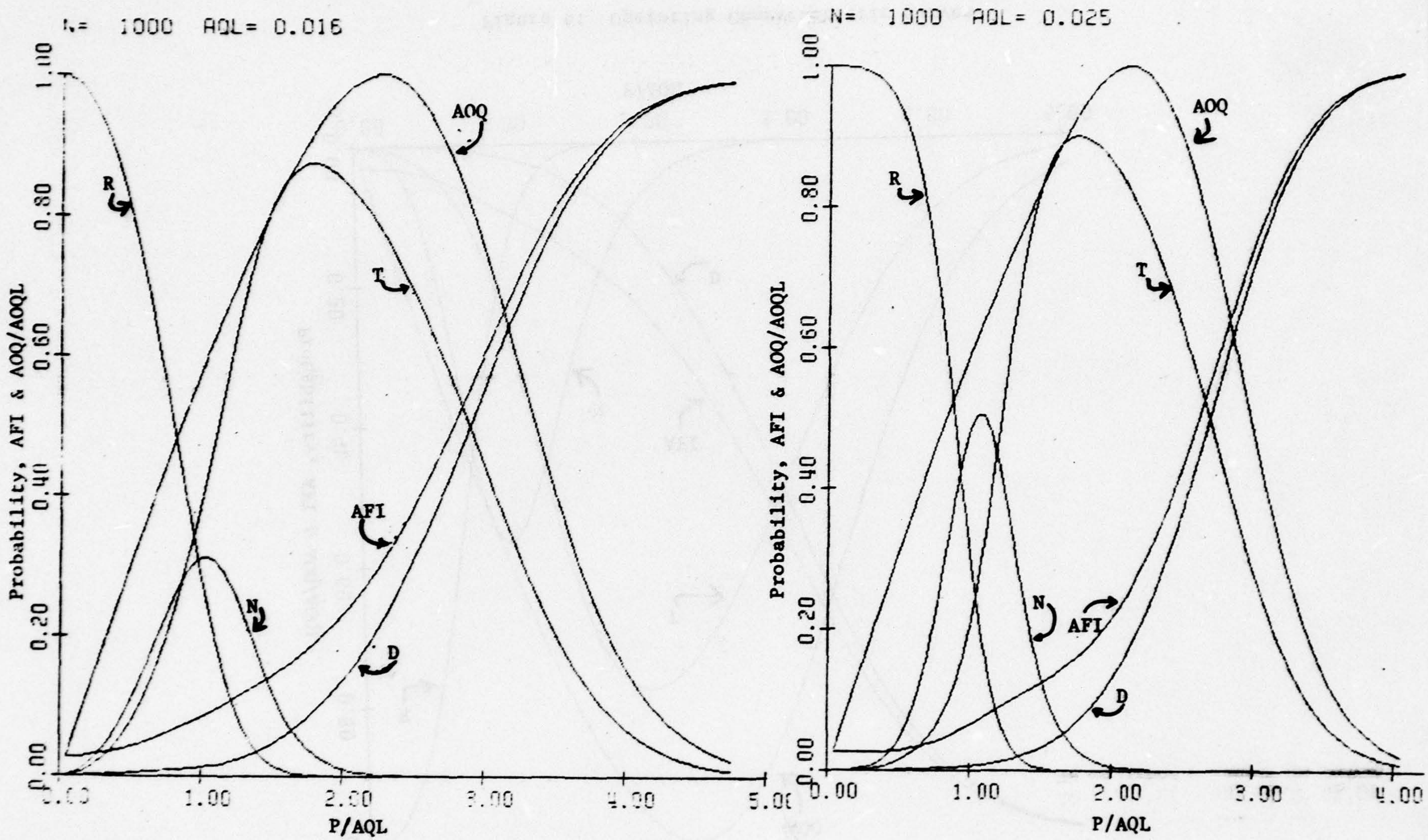


Figure 6: Operating Characteristic Curves

Code 6-4 and 6-5

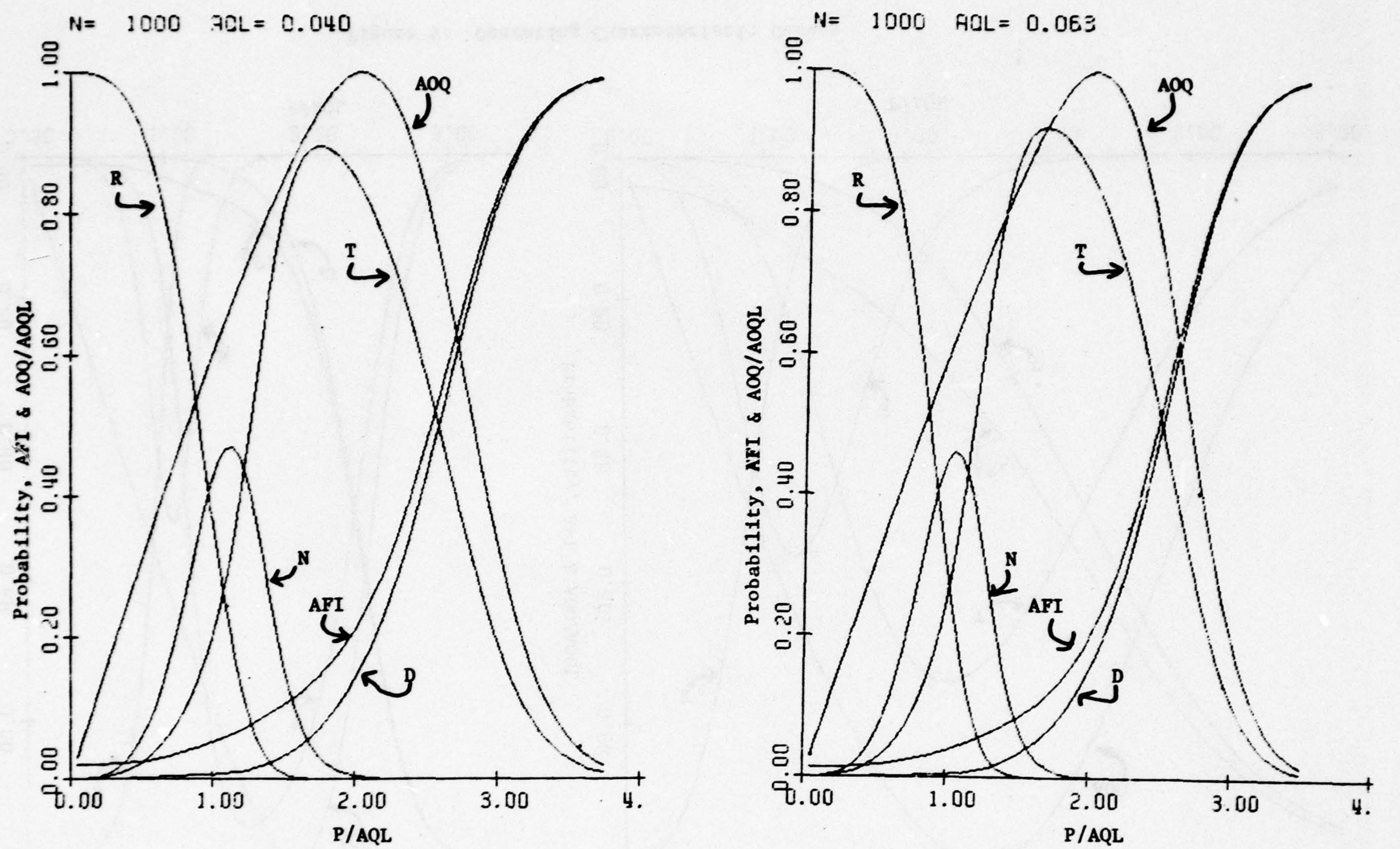


Figure 6: Operating Characteristic Curves

Code 6-6 and 6-7

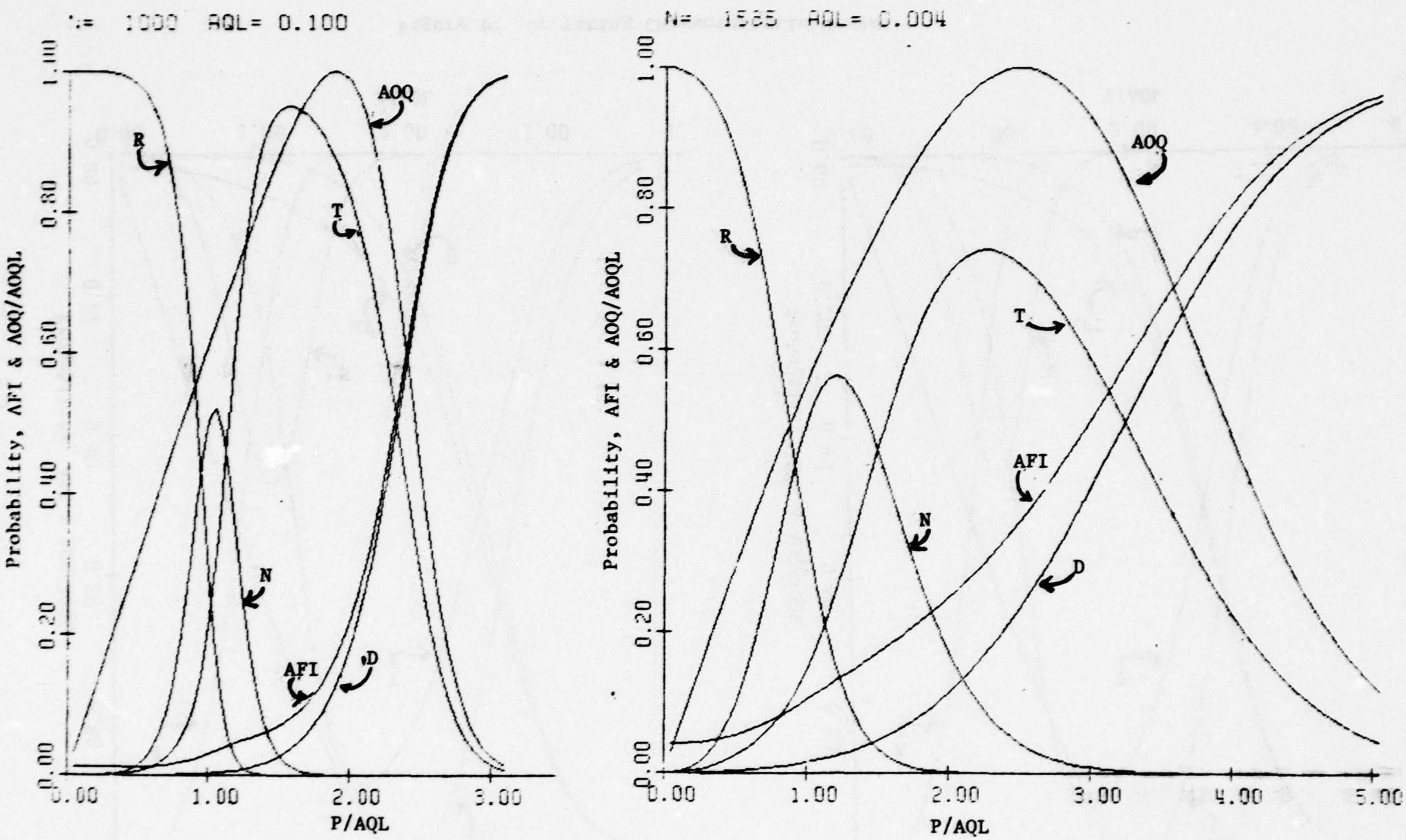


Figure 6: Operating Characteristic Curves

Code 6-8 and 7-1

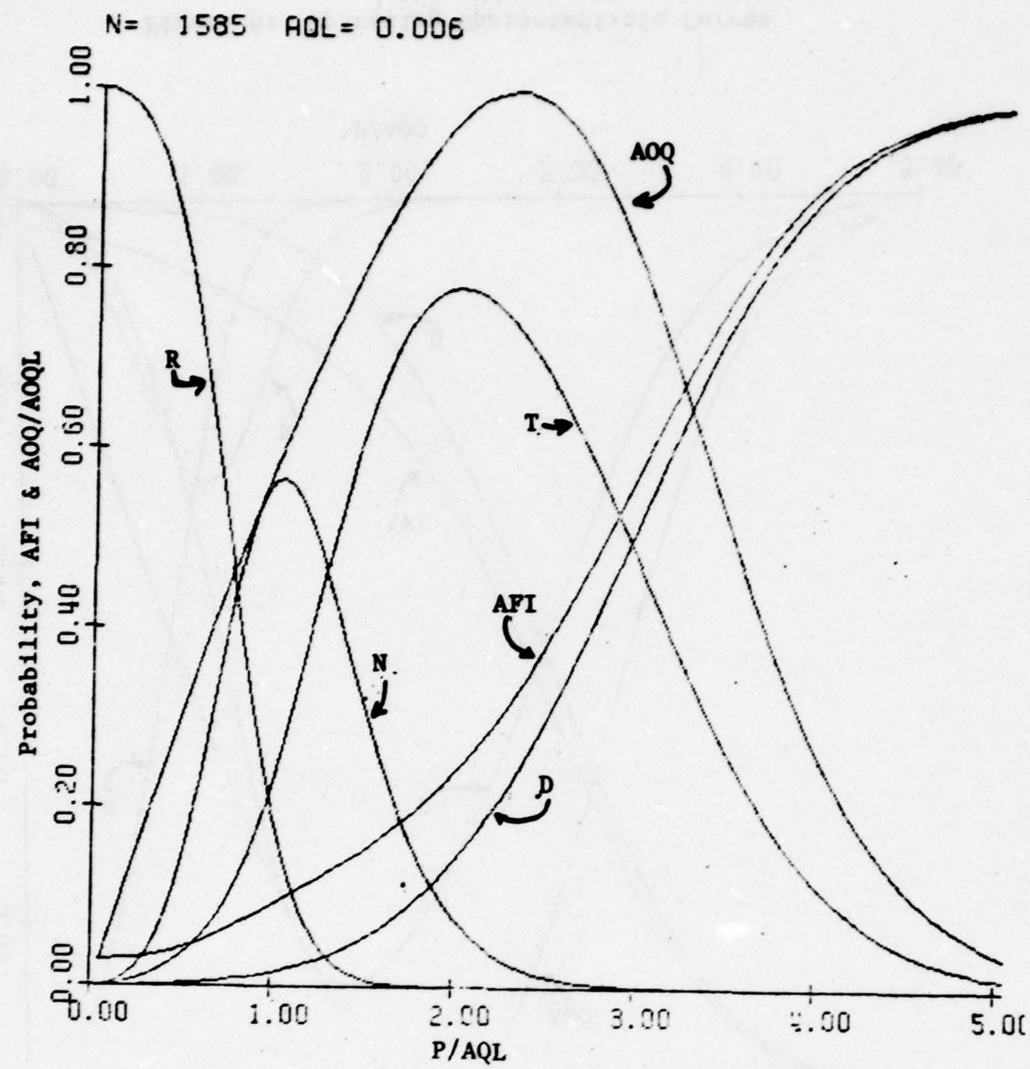


Figure 6: Operating Characteristic Curves

Code 7-2

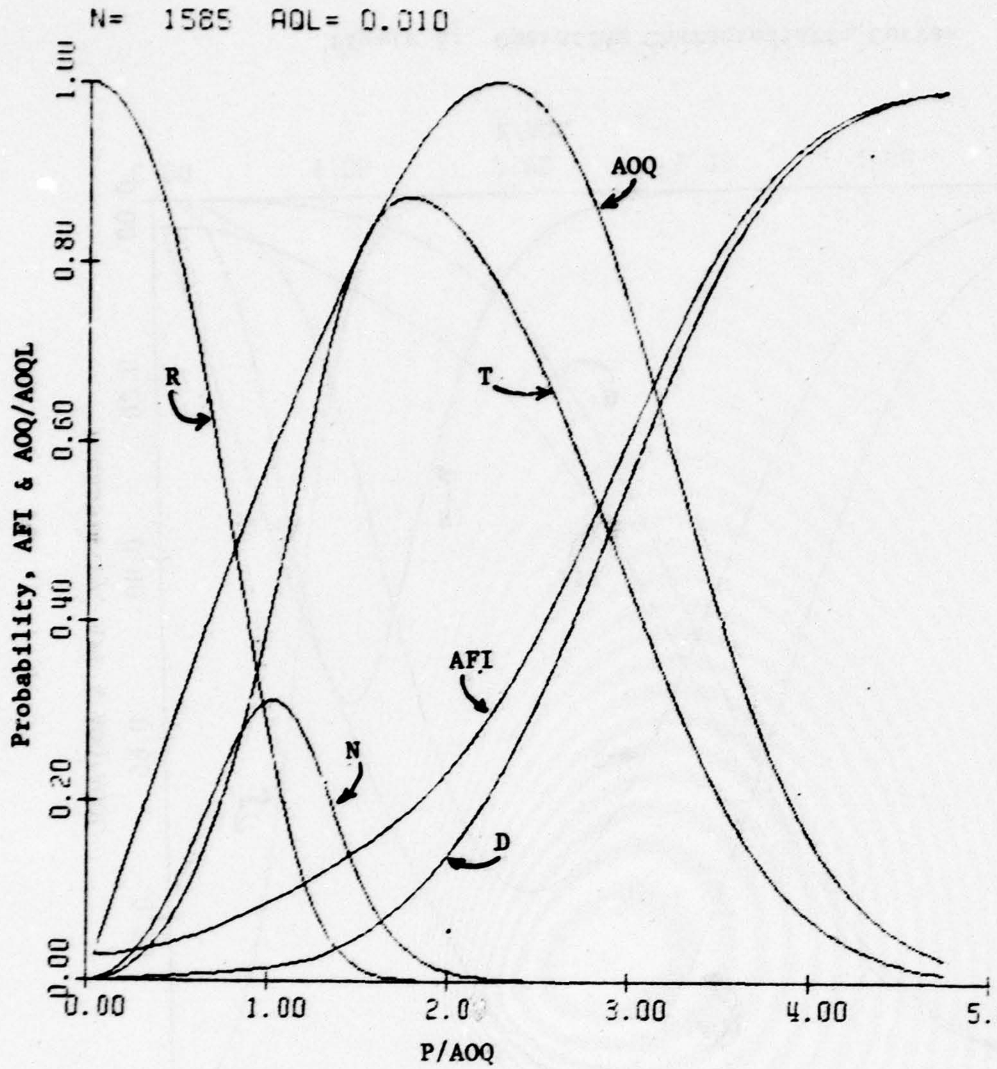


Figure 6: Operating Characteristic Curves

Code 7-3

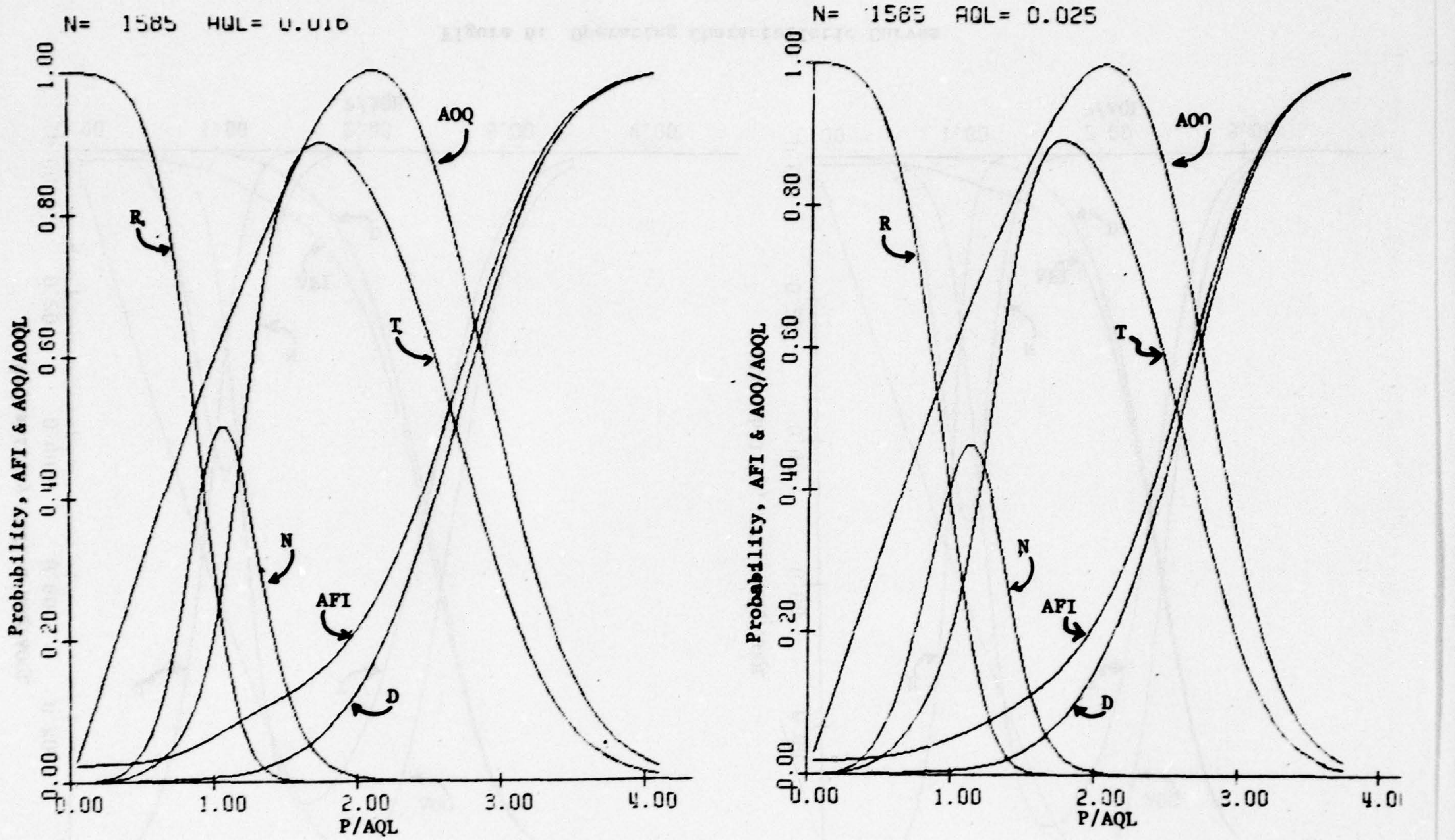


Figure 6: Operating Characteristic Curves

Code 7-4 and 7-5

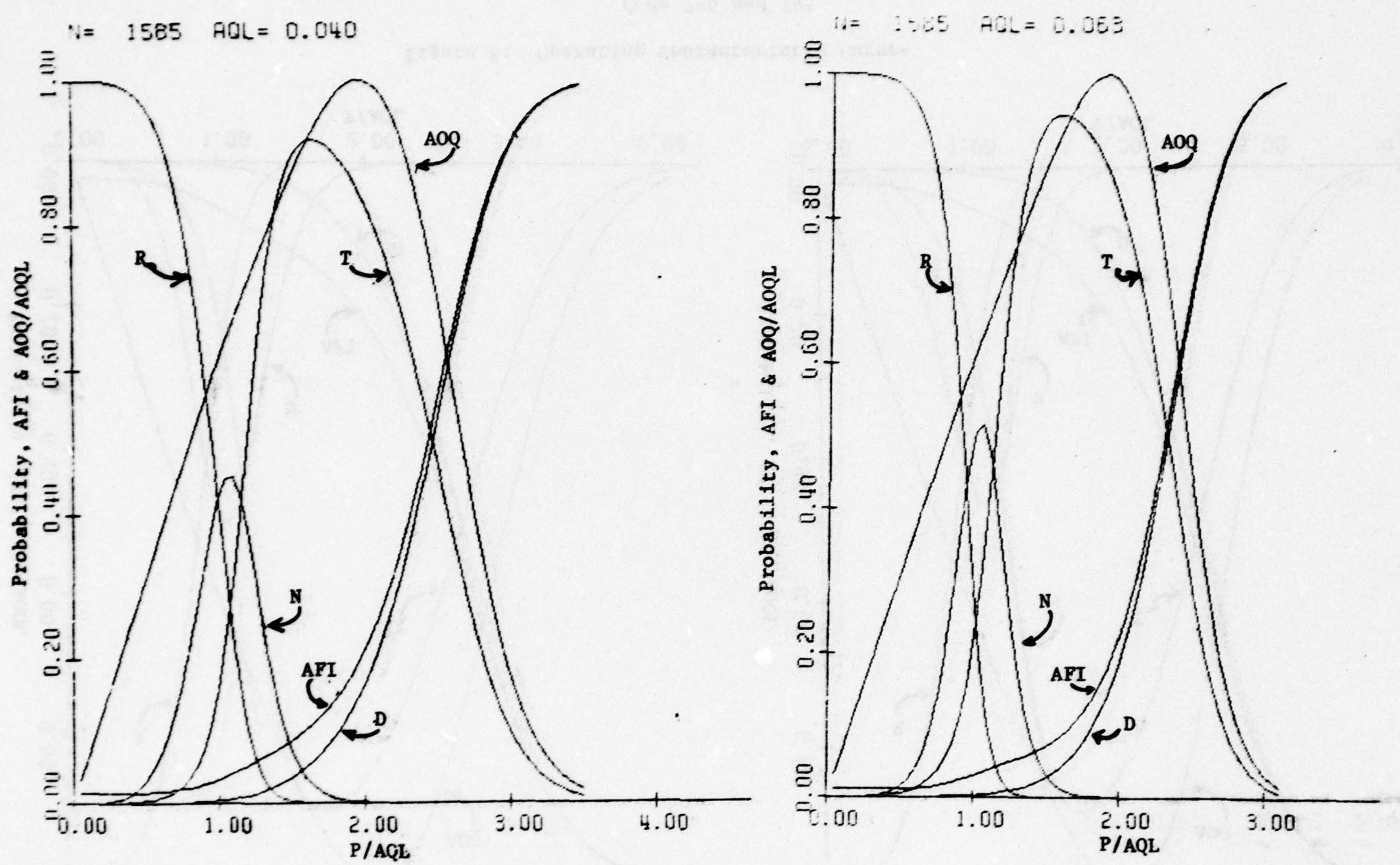


Figure 6: Operating Characteristic Curves

Code 7-6 and 7-7

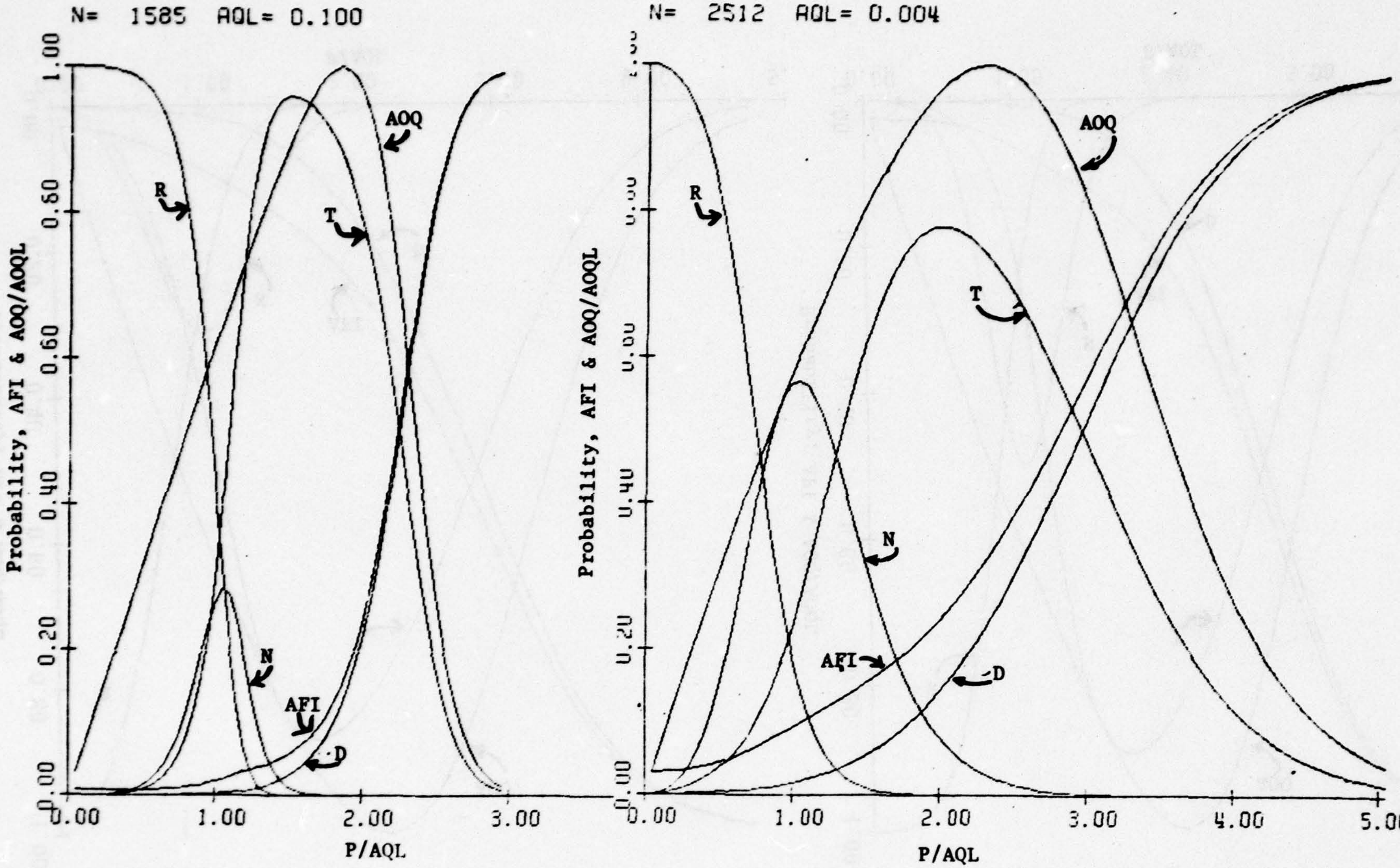


Figure 6: Operating Characteristic Curves

Code 7-8 and 8-1

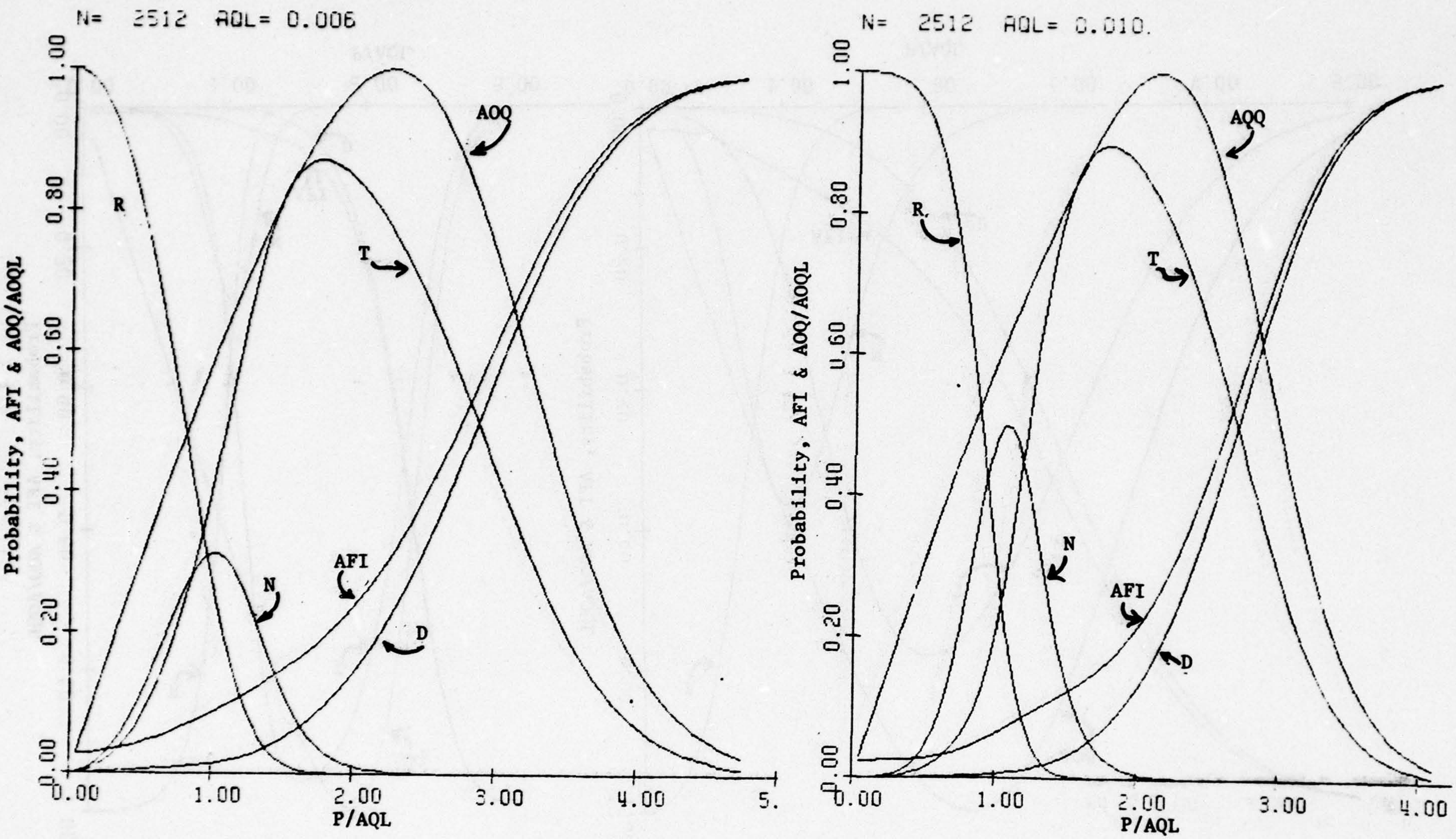
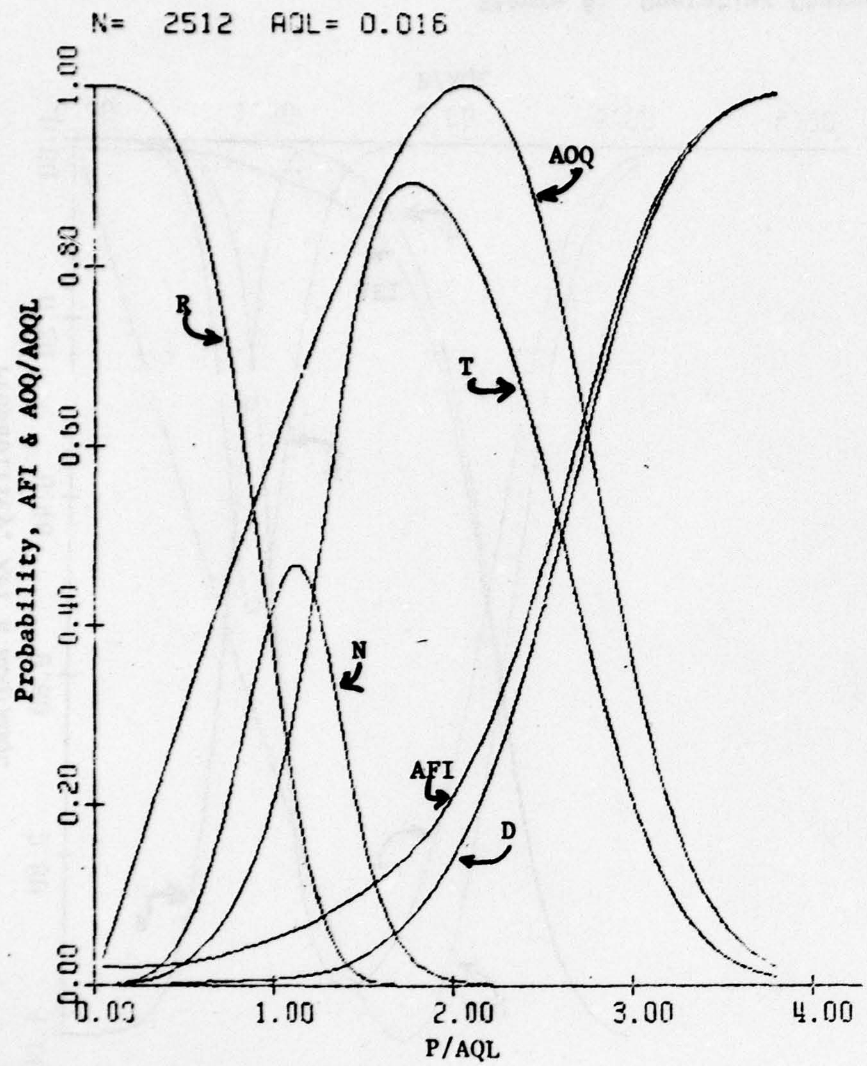


Figure 6: Operating Characteristic Curves

Code 8-2 and 8-3



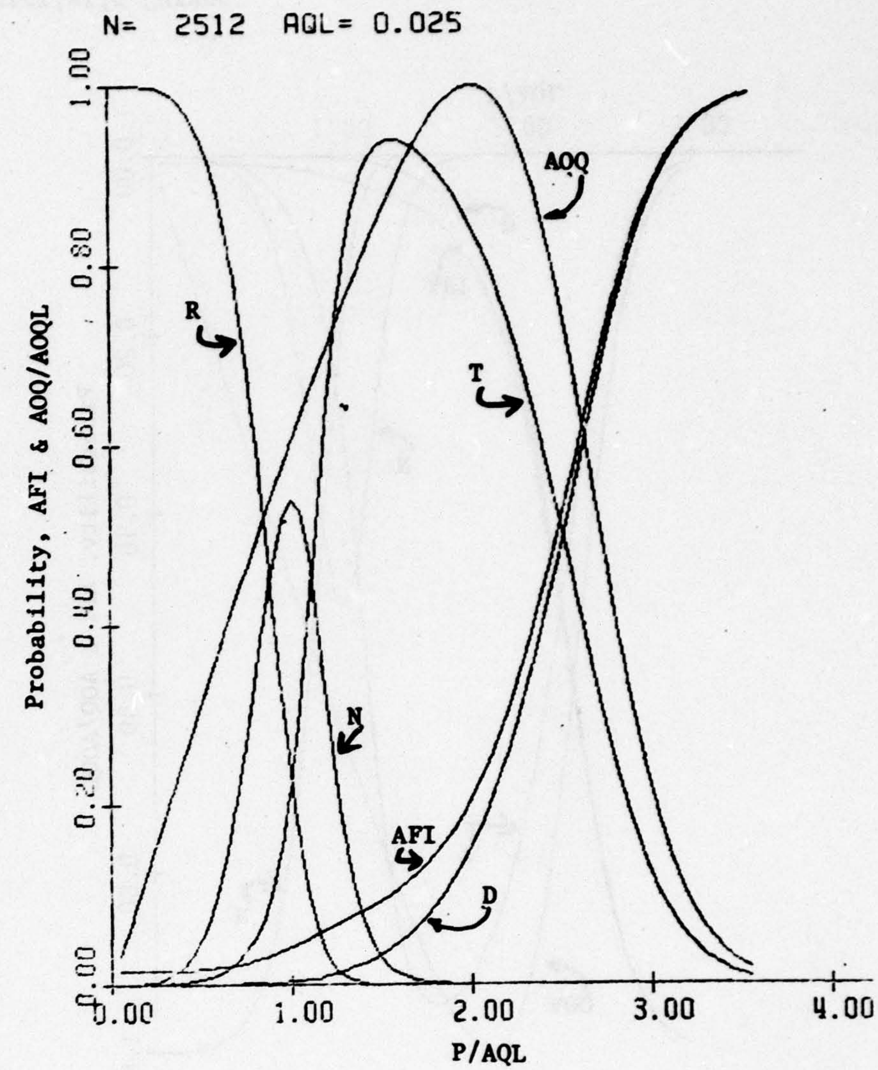


Figure 6: Operating Characteristic Curves

Code 8-4 and 8-5

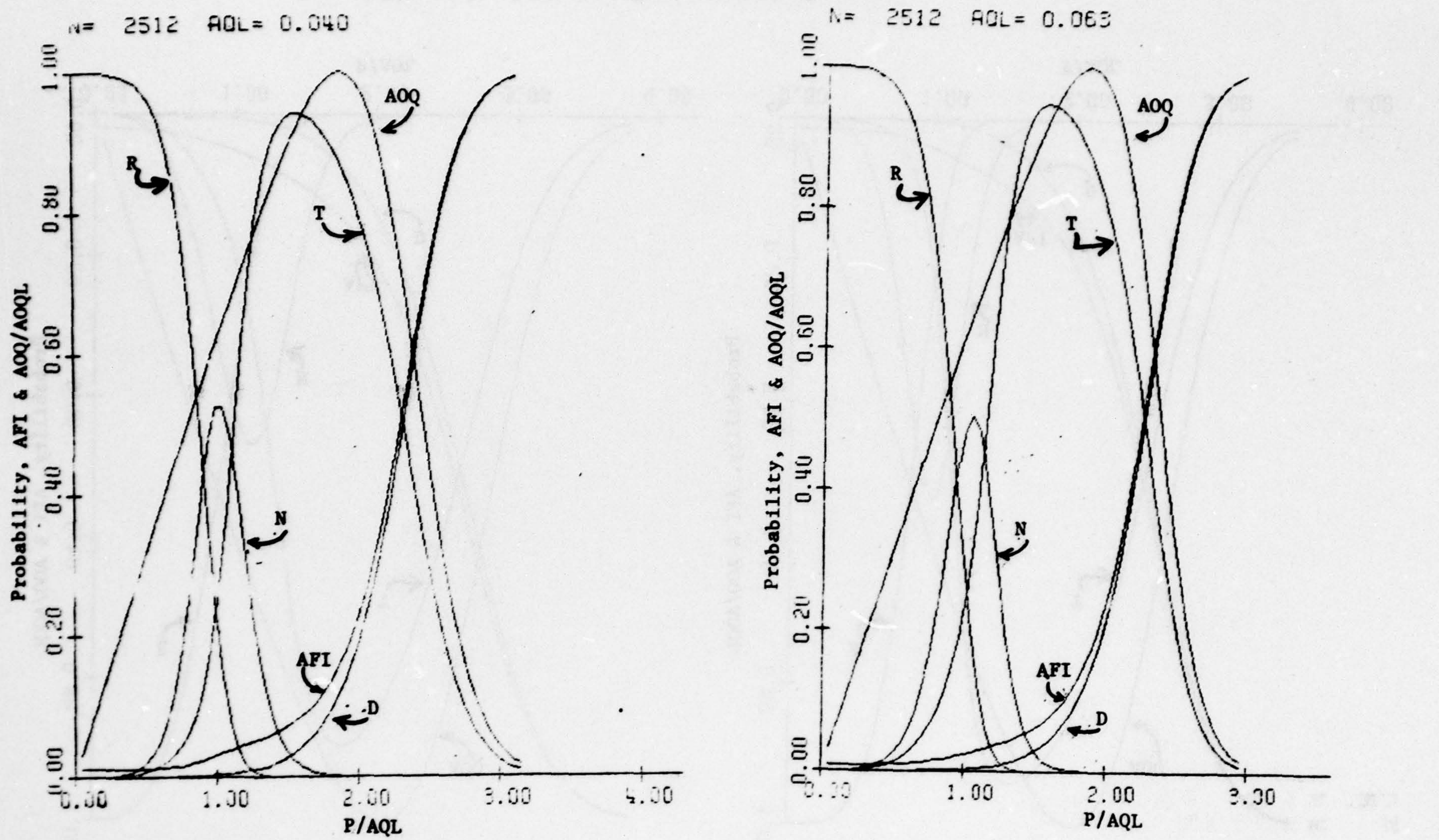


Figure 6: Operating Characteristic Curves

Code 8-6 and 8-7

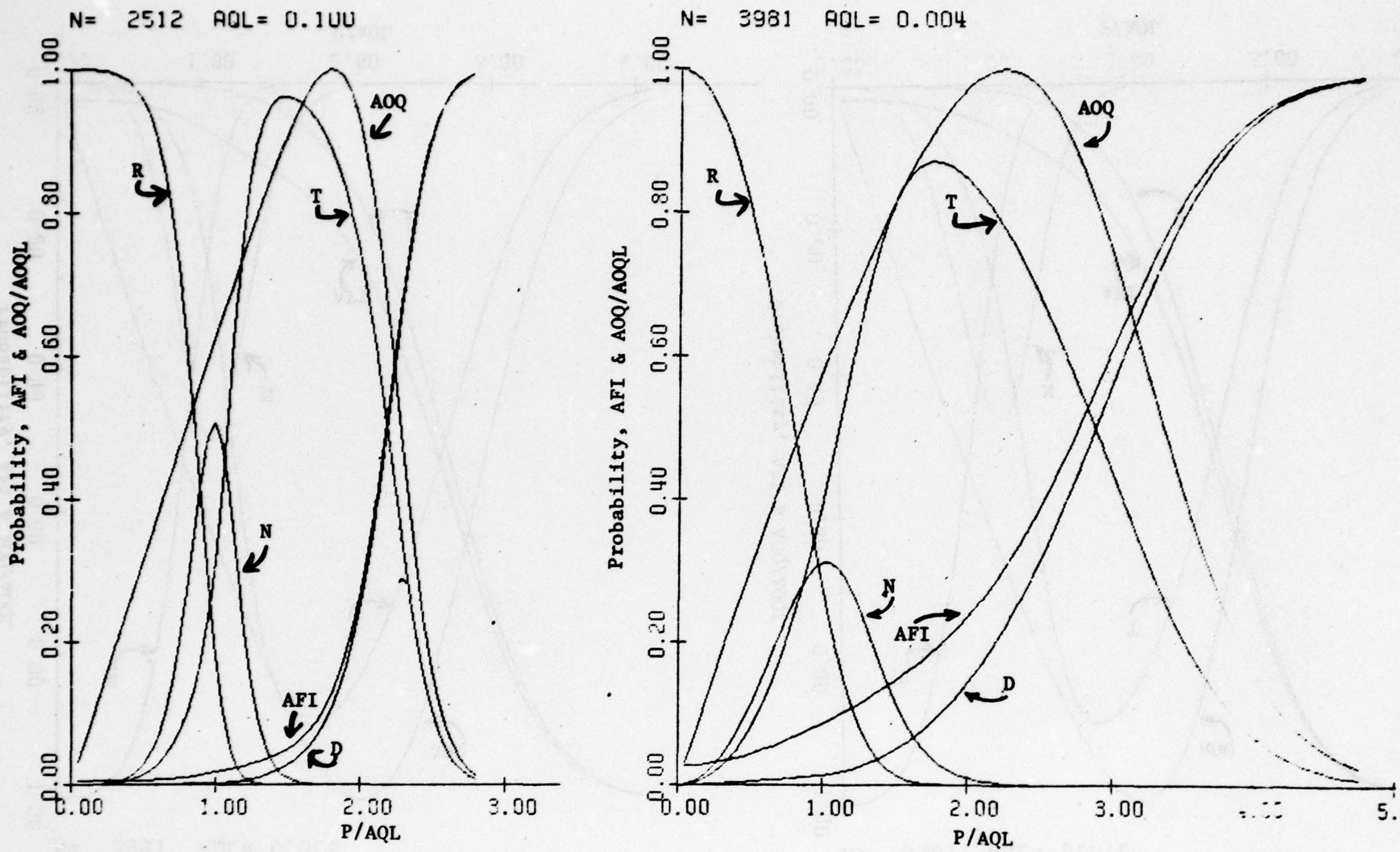


Figure 6: Operating Characteristic Curves

Code 8-8 and 9-1

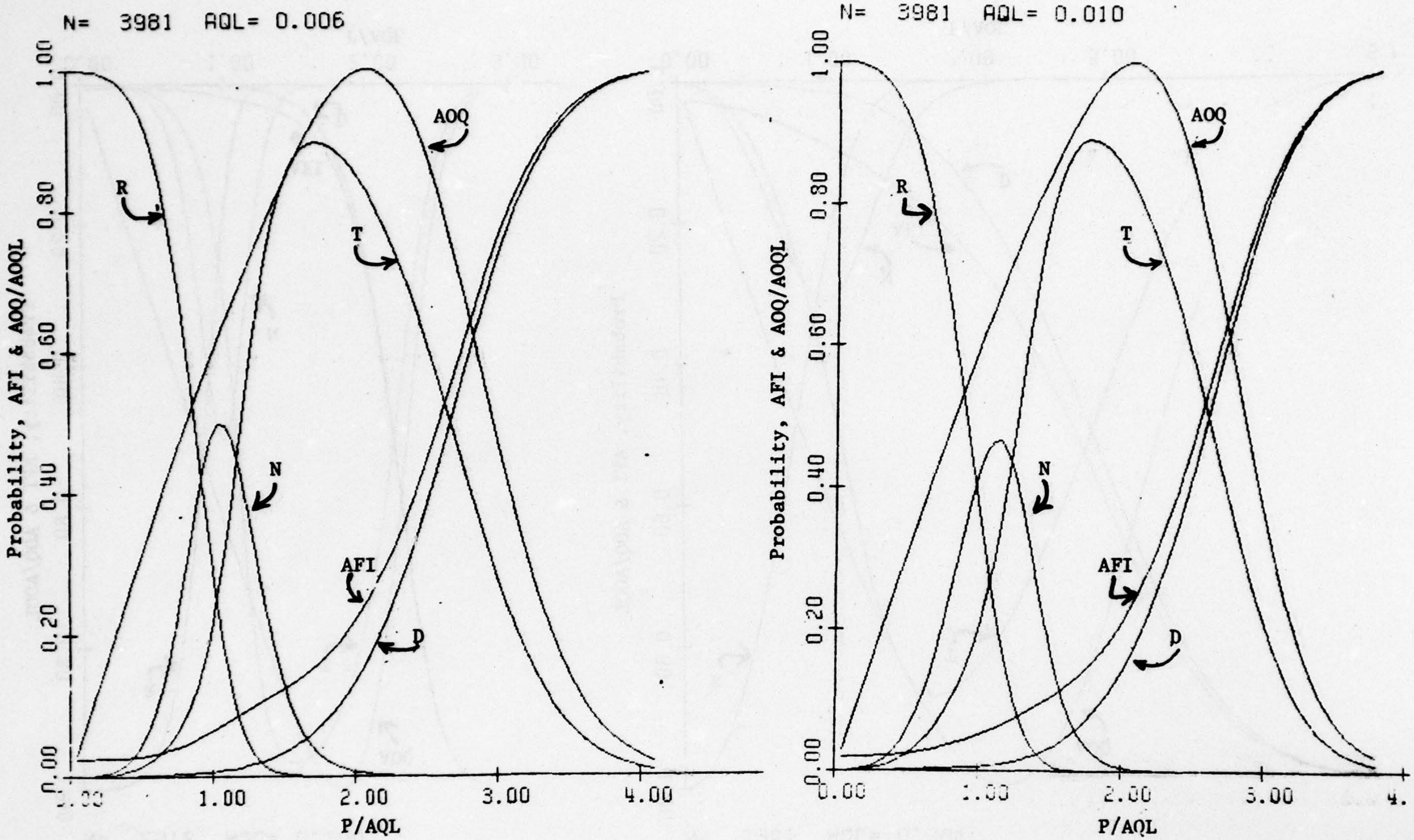


Figure 6: Operating Characteristic Curves

Code 9-2 and 9-3

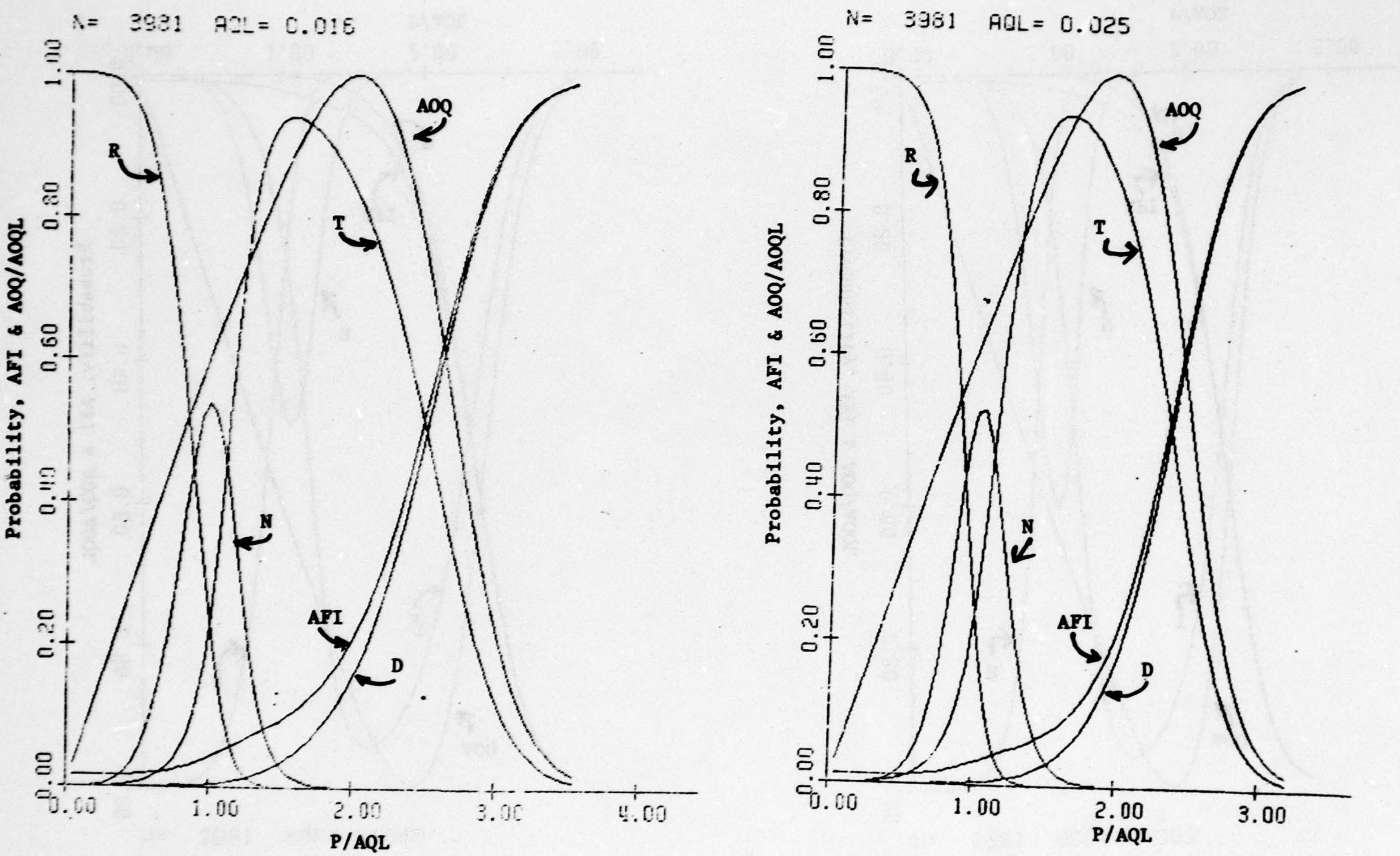
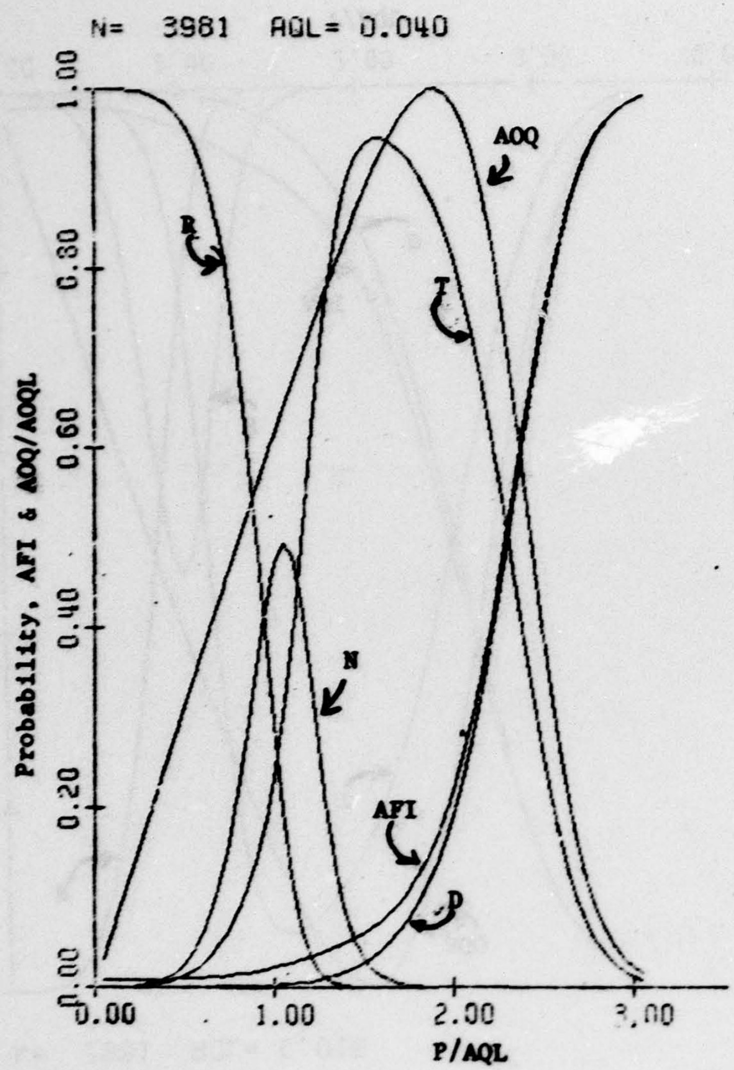


Figure 6: Operating Characteristic Curves

Code 9-4 and 9-5



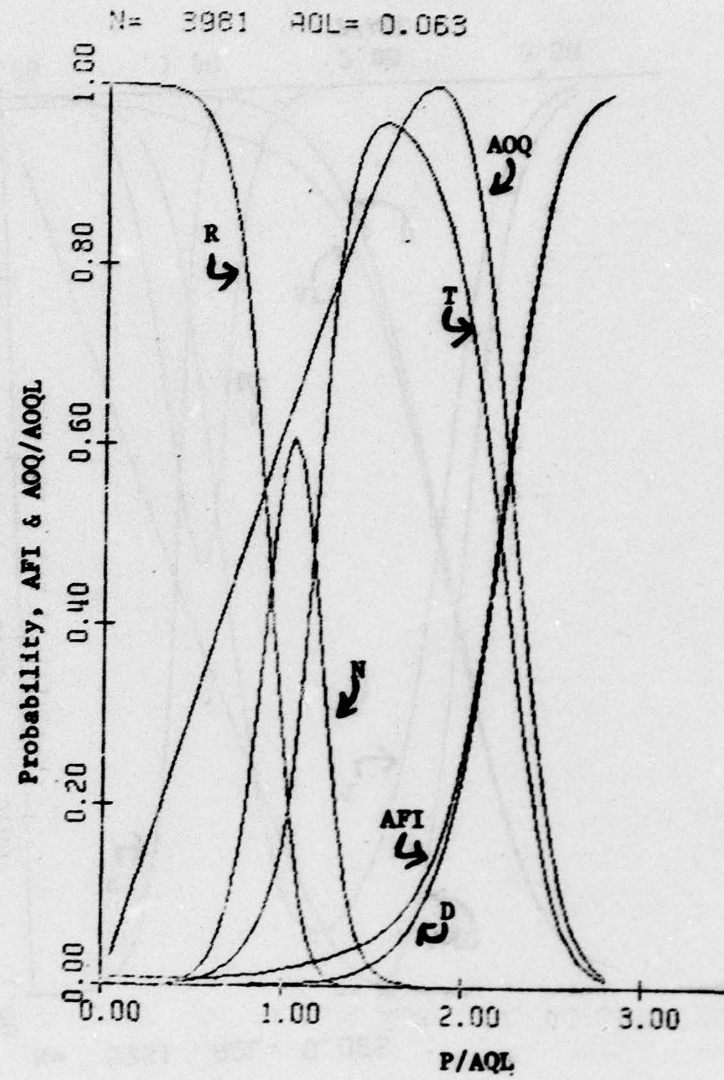


Figure 6: Operating Characteristic Curves

Code 9-6 and 9-7

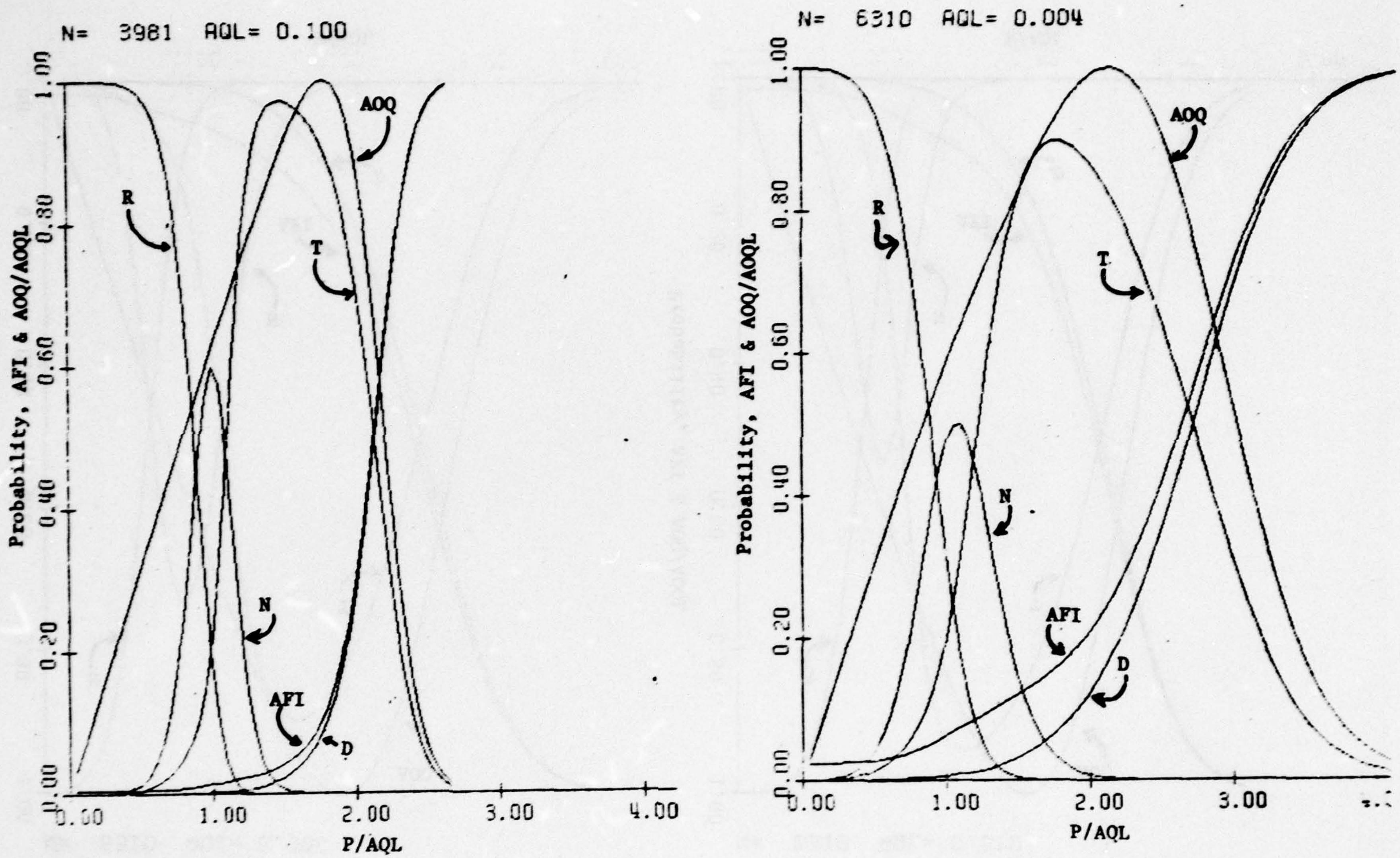


Figure 6: Operating Characteristic Curves

Code 9-8 and 10-1

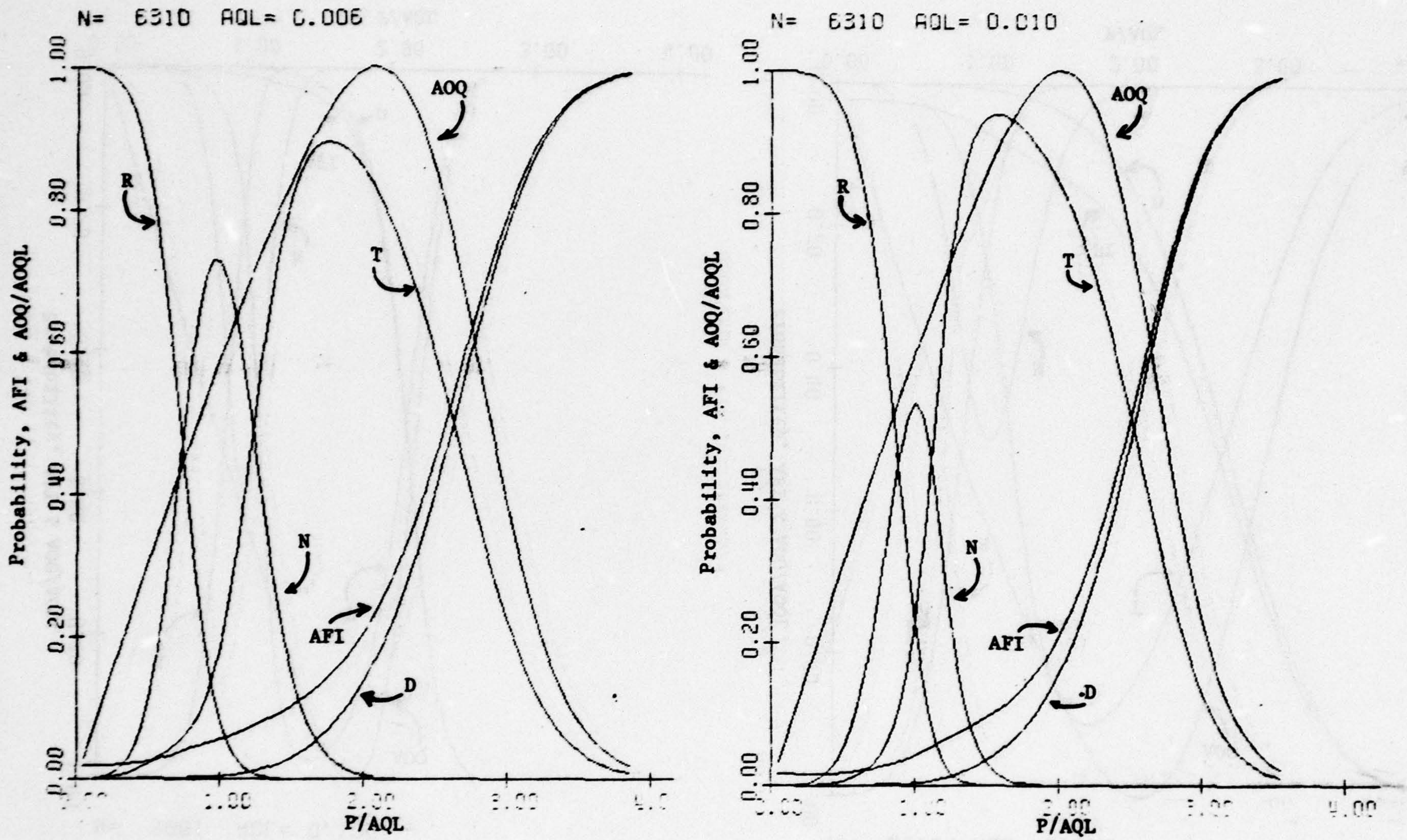


Figure 6: Operating Characteristic Curves

Code 10-2 and 10-3

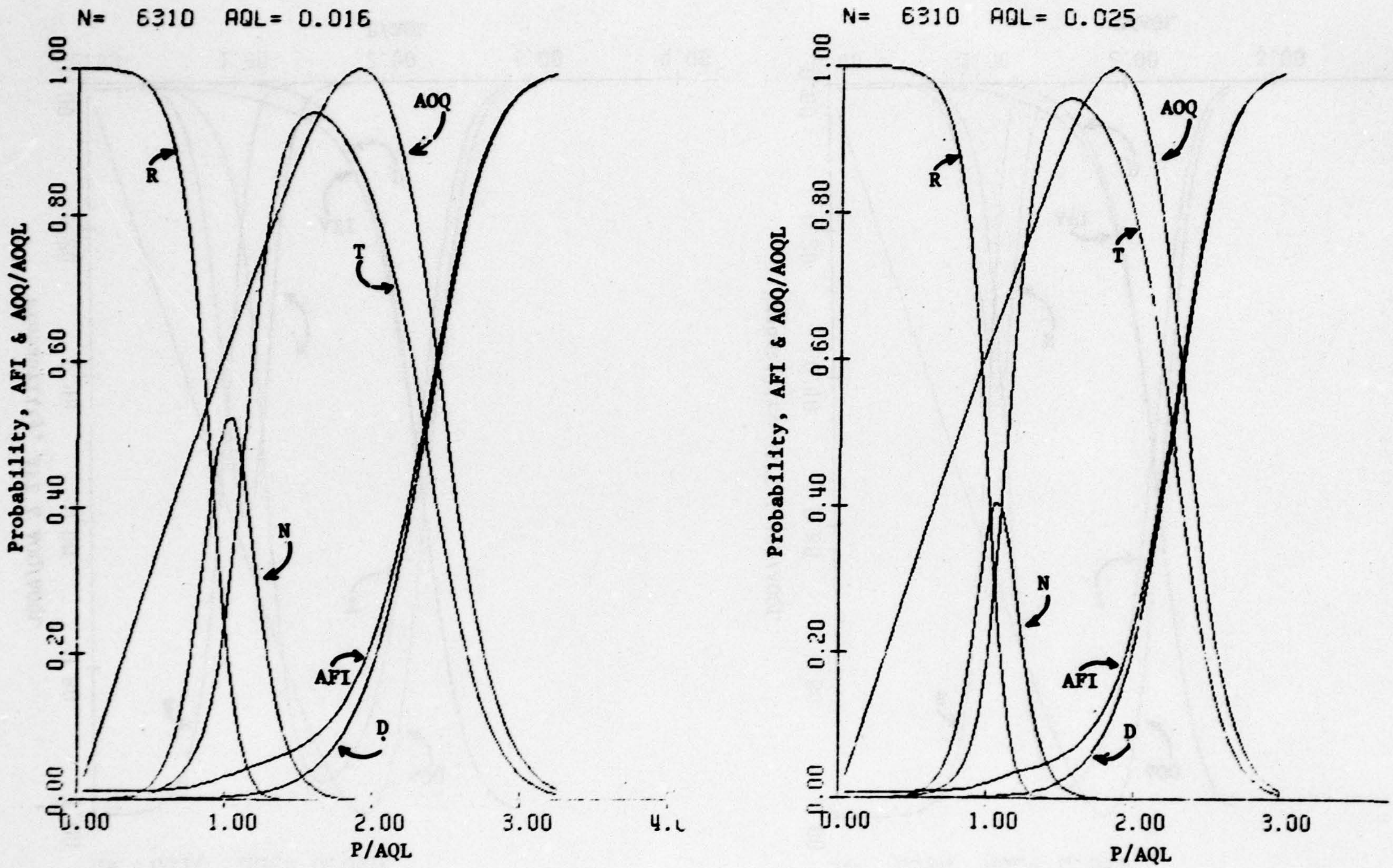


Figure 6: Operating Characteristic Curves

Code 10-4 and 10-5

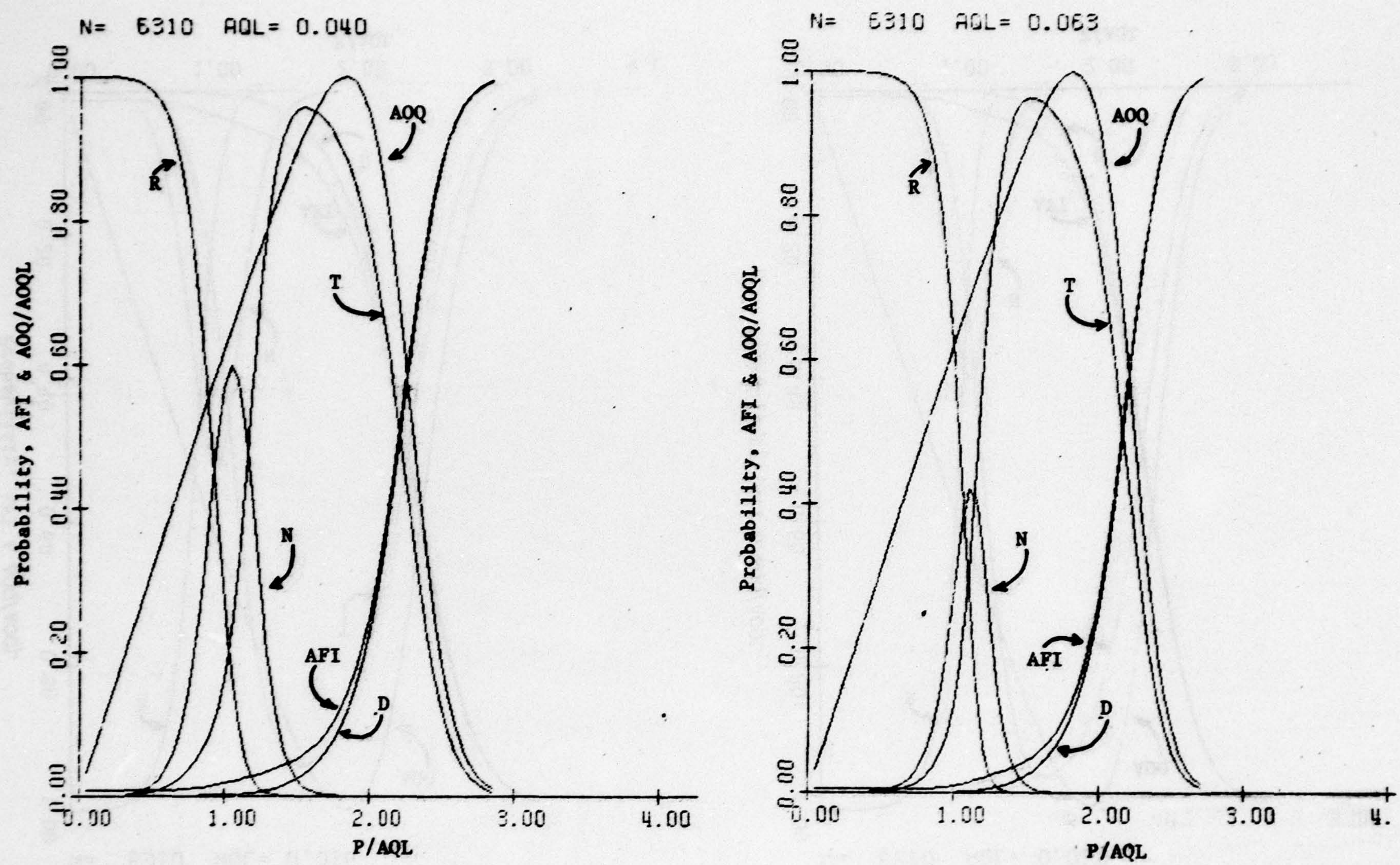


Figure 6: Operating Characteristic Curves

Code 10-6 and 10-7

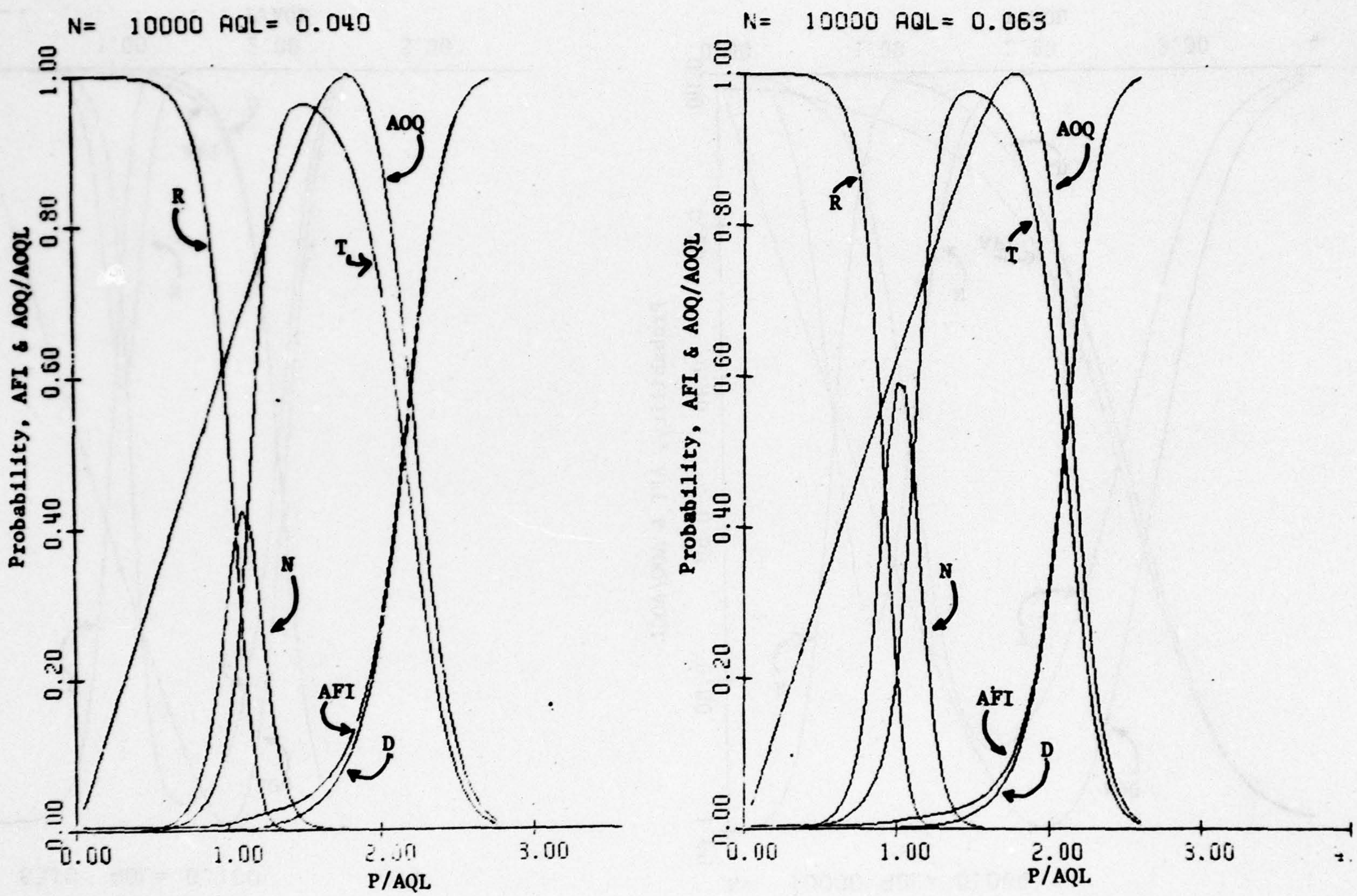


Figure 6: Operating Characteristic Curves

Code 11-6 and 11-7

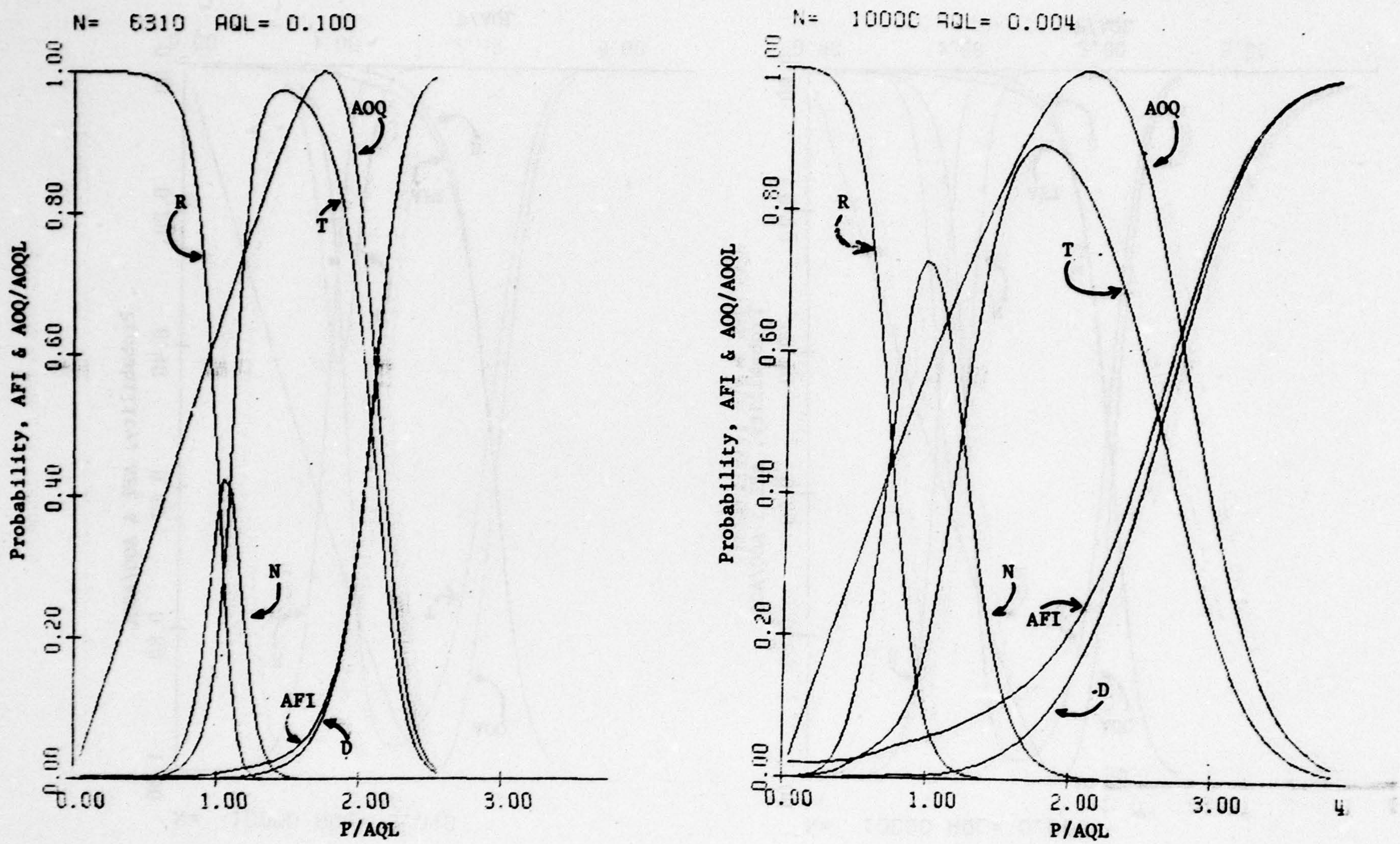


Figure 6: Operating Characteristic Curves

Code 10-8 and 11-1

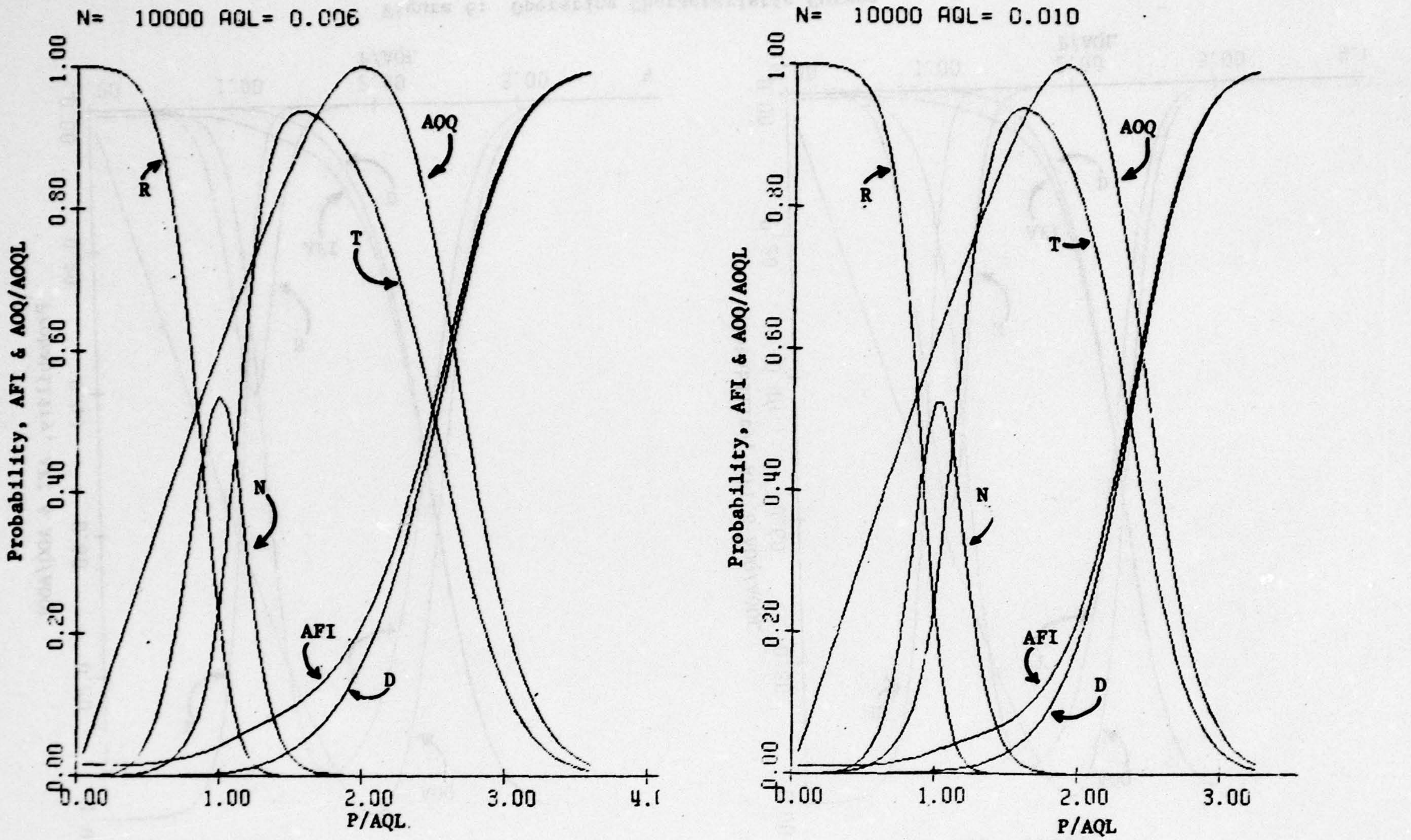


Figure 6: Operating Characteristic Curves

Code 11-2 and 11-3

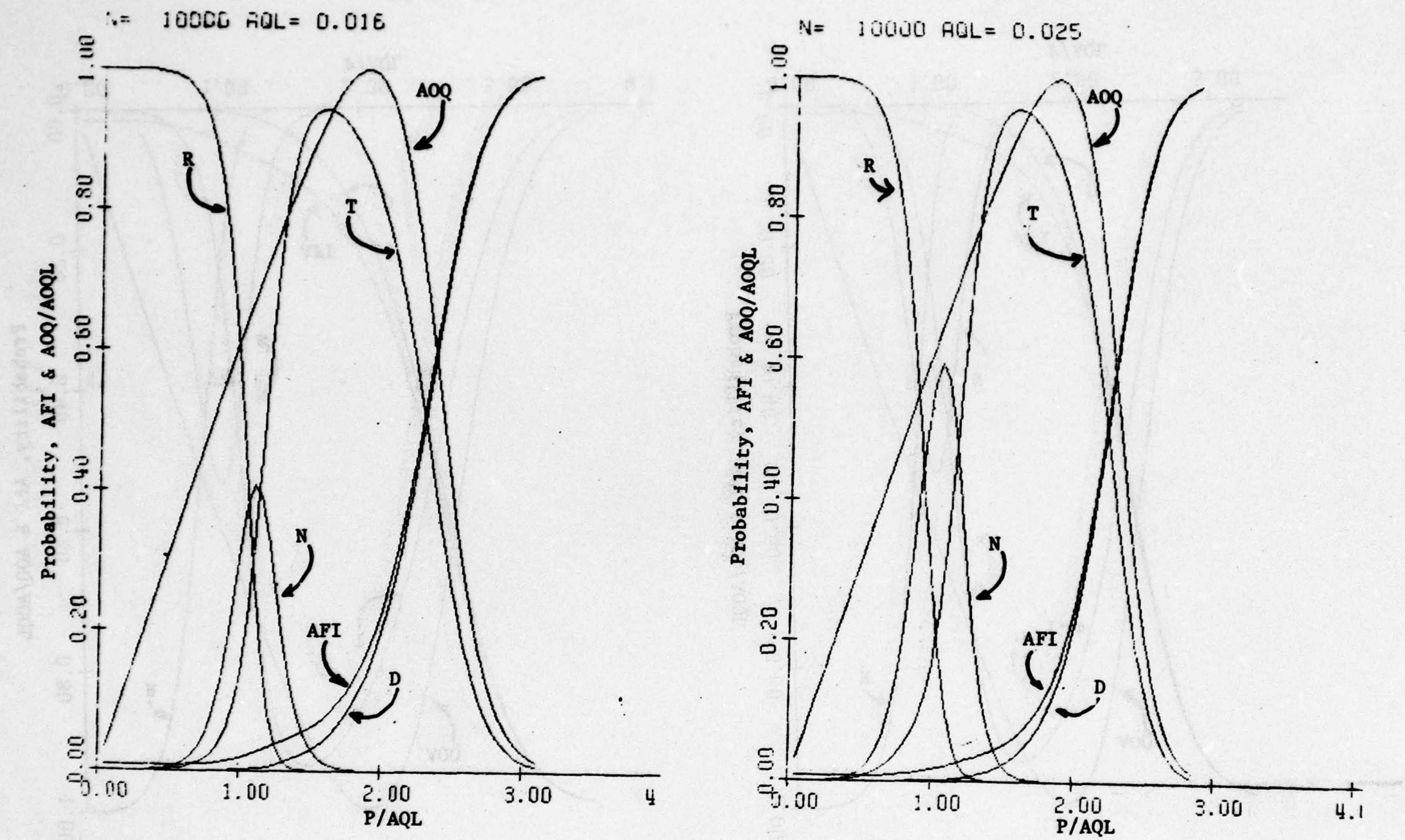


Figure 6: Operating Characteristic Curves

Code 11-4 and 11-5

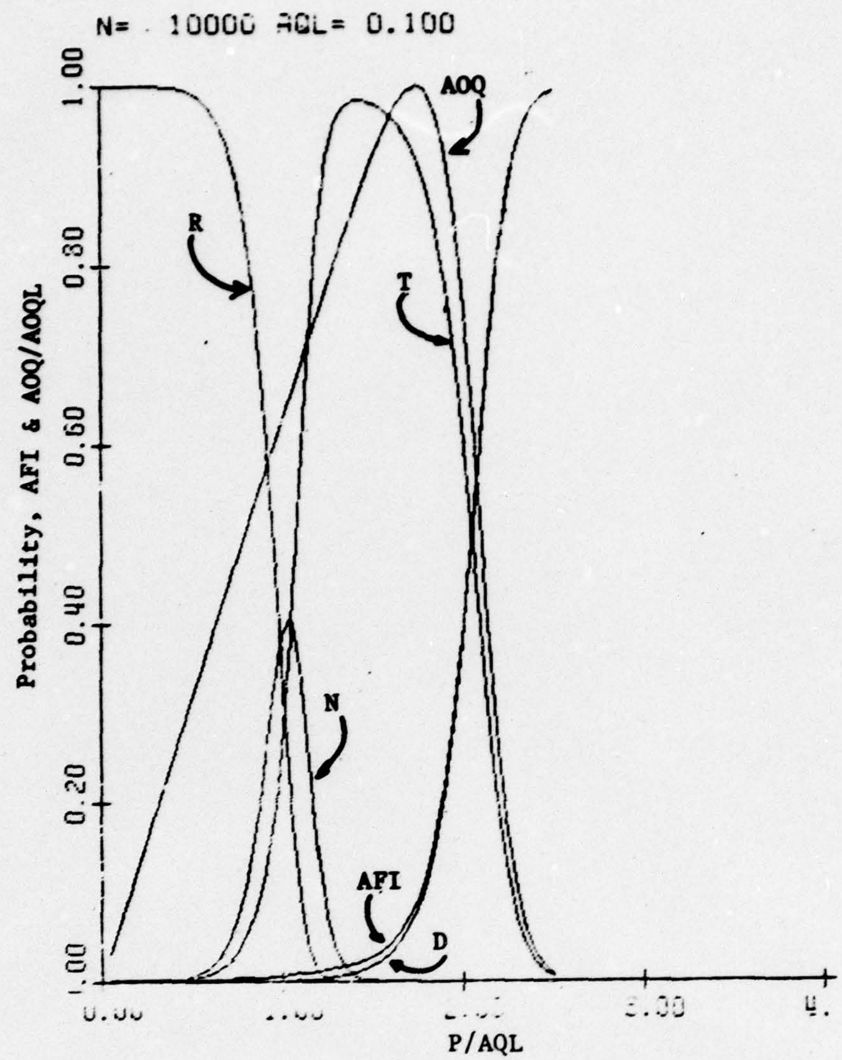


Figure 6: Operating Characteristic Curves

Code 11-8